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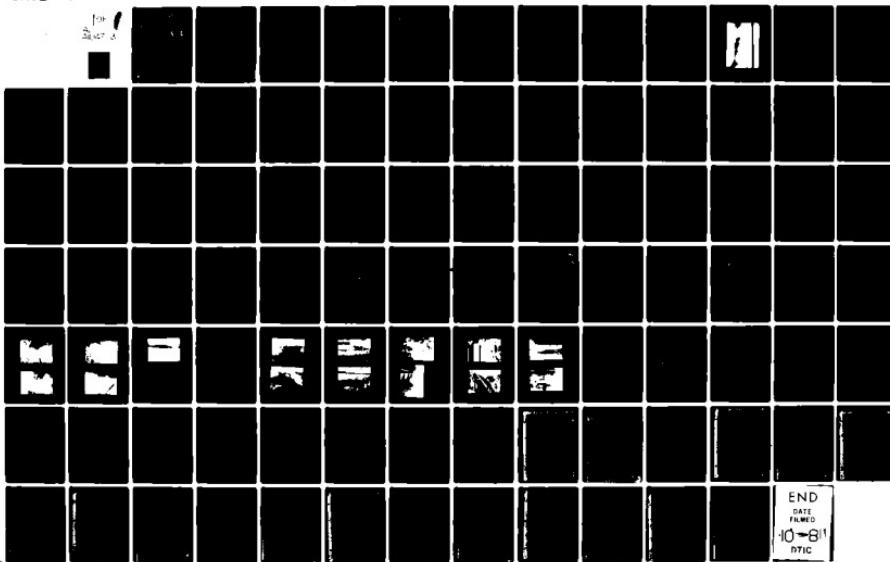
NATIONAL DAM SAFETY PROGRAM, C & A LAKE DAM (MO 10105) MISSISSI--ETC(U)

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## MISSISSIPPI-SALT-QUINCY RIVER BASIN

C & A LAKE DAM  
AUDRAIN COUNTY, MISSOURI  
MO. 65010



## PHASE I INSPECTION REPORT NATIONAL DAM SAFETY PROGRAM



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St. Louis District

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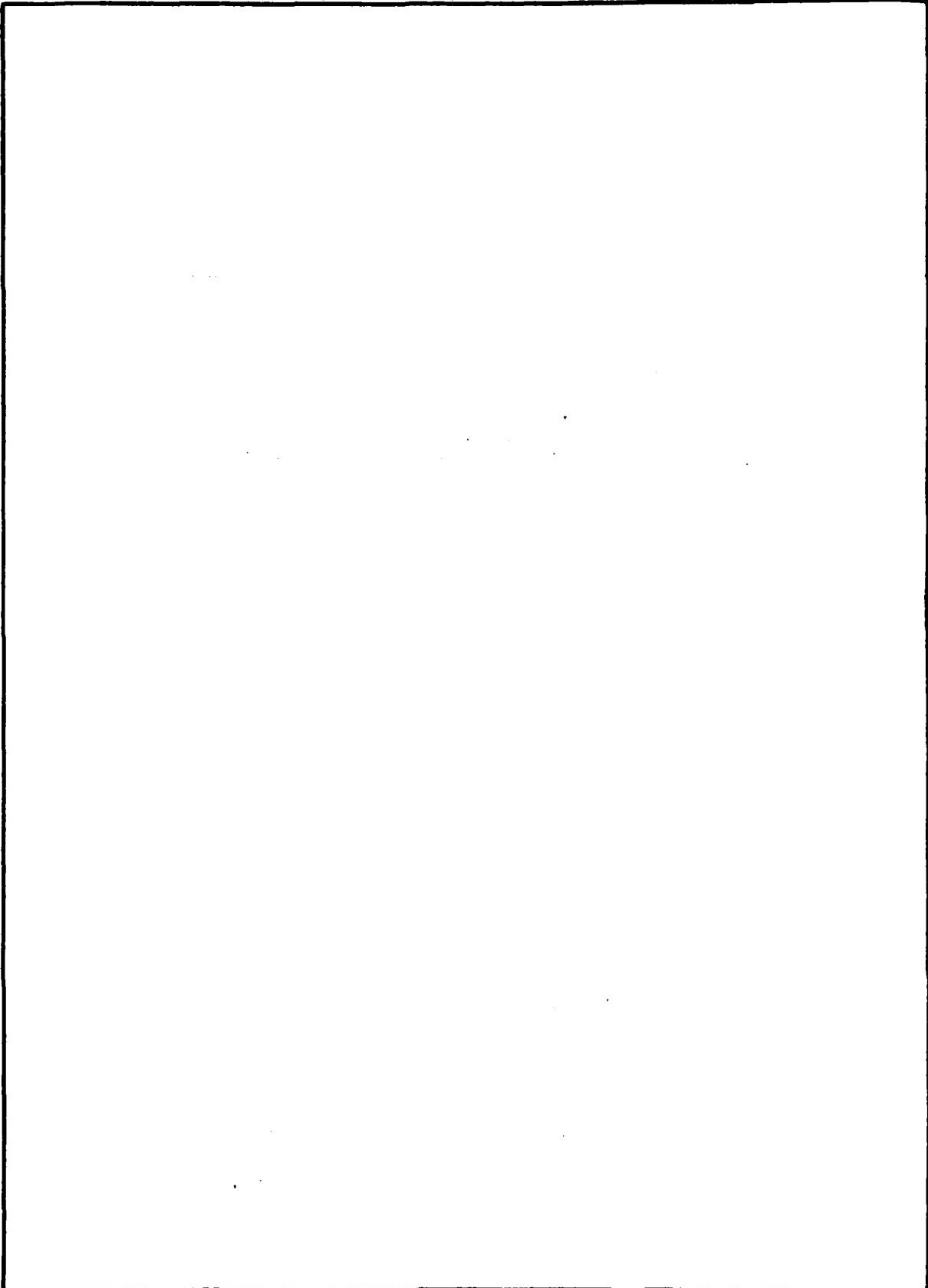
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Dam Safety, Lake, Dam Inspection, Private Dams		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.		

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SUBJECT: C & A Lake Dam (MO 10105), Phase I Inspection Report

This report presents the results of field inspection and evaluation of the C & A Lake Dam. It was prepared under the National Program of Inspection of Non-Federal Dams.

SUBMITTED BY:

Chief, Engineering Division

Date

APPROVED BY:

Colonel, CE, District Engineer

Date

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C & A LAKE DAM  
AUDRAIN COUNTY, MISSOURI

MISSOURI INVENTORY NO. 10105

PHASE I INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM

PREPARED BY  
CONSOER, TOWNSEND AND ASSOCIATES, LTD.  
ST. LOUIS, MISSOURI  
AND  
ENGINEERING CONSULTANTS, INC.  
ENGLEWOOD, COLORADO  
A JOINT VENTURE

UNDER DIRECTION OF  
ST. LOUIS DISTRICT, CORPS OF ENGINEERS  
FOR  
GOVERNOR OF MISSOURI

DECEMBER 1979

PHASE I INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM

Name of Dam: C & A Lake Dam, Missouri Inv. No. 10105  
State Located: Missouri  
County Located: Audrain  
Stream: An Unnamed Tributary of the South Fork Salt River  
Date of Inspection: June 11, 1979 and October 13, 1979

Assessment of General Condition

C & A Lake Dam (a railroad embankment which is the main dam, and a check dam) was inspected by the engineering firms of Consoer, Townsend, and Associates, Ltd. and Engineering Consultants, Inc. (A Joint Venture) of St. Louis, Missouri according to the "Recommended Guidelines for Safety Inspection of Dams". These guidelines were developed by the Chief of Engineers, U.S. Army, Washington, D.C., with the help of Federal and State agencies, professional engineering organizations, and private engineers. The resulting guidelines are considered to represent a consensus of the engineering profession.

In the guidelines, the dams (the main dam and the check dam) are in significant hazard potential classification. Significant hazard potential category structures will be those located in predominantly rural or agricultural areas where failure may damage isolated homes, secondary highways or minor railroads or cause interruption of use or service of relatively important public

- 3 -

utilities. The main dam is classified as small in the dam size category because its height is less than 40 feet, and it impounds less than 1,000 acre-feet of water. The check dam, which is three feet in height, forms a continuous barrier to the impoundment created by the main dam.

Our inspection and evaluation indicates that the spillway of C & A Lake Dam does not meet the criteria set forth in the guidelines for dams having the above size and hazard potential. C & A Lake Dam being a small size dam with a significant hazard potential, is required by the guidelines to pass from 100-year to one-half of the Probable Maximum Flood without overtopping. Since there is significant hazard potential downstream of the dam and because of its location just upstream of a highway, the appropriate spillway design flood for C & A Lake Dam is one-half of the Probable Maximum Flood. It was determined that the reservoir/spillway system can accommodate only 6 percent of the Probable Maximum Flood without overtopping the check dam. However, the main dam is not overtopped during the occurrence of the Probable Maximum Flood. Our evaluation indicates that the reservoir/spillway system can not even accommodate the 10-year flood without overtopping the check dam.

The Probable Maximum Flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region. The 10-year flood is defined as a flood having a 10 percent chance of being equalled or exceeded during any given year.

Other deficiencies noted by the inspection team were: the heavy growth of vegetation on the upstream slope of the main dam; depressions on the crest of the check dam; heavy vegetation in the downstream channel; undercutting of the spillway at the

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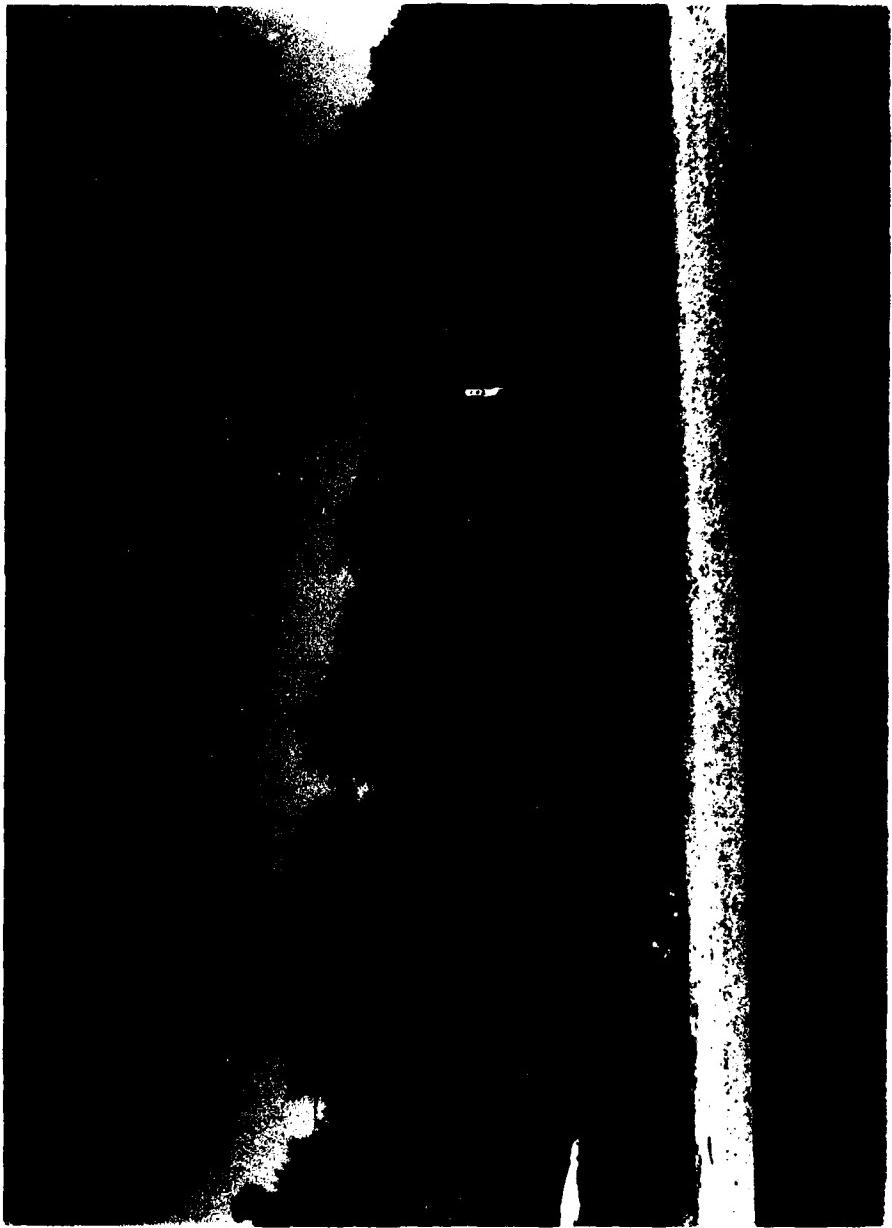
downstream end; lack of riprap protection for the main dam; lack of adequate riprap protection for the check dam; the heavy growth of vegetation on the downstream slope of the main dam; a need for periodic inspection by a qualified engineer and a lack of maintenance schedule. The lack of seepage and stability analyses on record is also a deficiency that should be corrected.

It is recommended that the owners take action to correct or control the deficiencies described above.



Walter G. Shifrin, P.E.





Overview of C & A lake Dam

PHASE I INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM

C & A LAKE DAM, I.D. No. 10105

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PHASE I INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM

C & A LAKE DAM, Missouri Inv. No. 10105

SECTION 1: PROJECT INFORMATION

1.1        General

a.        Authority

The Dam Inspection Act, Public Law 92-367 of August, 1972, authorizes the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspections. Inspections for the main dam and the check dam of C & A Lake were carried out under Contract DACW 43-79-C-0075 between the Department of the Army, St. Louis District, Corps of Engineers, and the engineering firms of Consoer, Townsend & Associates, Ltd., and Engineering Consultants, Inc. (A Joint Venture), of St. Louis, Missouri.

b.        Purpose of Inspection

The visual inspections of C & A Lake Dam were made on June 11 and October 13, 1979. The purpose of the inspections was to make a general assessment as to the structural integrity and operational adequacy of the dam embankments and their appurtenant structures.

c. Scope of Report

This report summarizes available pertinent data relating to the project; presents a summary of visual observations made during the field inspection; presents an assessment of hydrologic and hydraulic conditions at the site; presents an assessment as to the structural adequacy of the various project features; and assesses the general condition of the dams with respect to safety.

Subsurface investigations, laboratory testing, and detailed analyses were not within the scope of this study. No warranty as to the absolute safety of the project features is implied by the conclusions presented in this report.

It should be noted that reference in this report to left or right abutments is as viewed looking downstream. Left abutment or left side of the dam as used in this report refers to the southwest abutment or side and right, to the northeast abutment or side.

d. Evaluation Criteria

Criteria used to evaluate the dams were furnished by the Department of the Army, Office of the Chief of Engineers, in the publication "Recommended Guidelines for Safety Inspection of Dams", Appendix D. These guidelines were developed with the help of several Federal agencies and many State agencies, professional engineering organizations, and private engineers.

1.2        Description of the Project

a.        Description of Dams and Appurtenances

It should be noted that design drawings are not available for the dams or appurtenant structures. The following description is based exclusively on observations and measurements made during the visual inspections.

The reservoir is created by two embankments, a main dam and a check dam. The main dam consists of an earthfill embankment which supports the Illinois Central Gulf and Burlington Northern railroad track. The embankment is straight in alignment. The crest width of 8.5 feet with a length of approximately 900 feet. The elevation of the top of the rails of the track is 754.8 feet above M.S.L. and the maximum embankment height is 27 feet. (The elevation of the top of rails is derived by assuming the crest of the spillway to be at 741 feet above M.S.L.) The upstream and downstream slopes of the embankment were measured to be approximately 1V to 1.5H.

The check dam consists of an earthfill embankment with about a right angle bend in its alignment. The right side of the embankment abuts the main dam at approximately 100 feet to the right of the left abutment of the main dam and the left side of the embankment abuts U.S. Highway 54 on the west side of the lake. The crest width is 4 feet with a length of approximately 182 feet. The elevation of the crest is 743.3 feet above M.S.L. and the maximum embankment height is about 3 feet.

The downstream slope of the check dam was measured to be approximately 1V to 3H. The upstream slope was also found to be approximately 1V to 3H from the crest to the water's edge. At the time of the inspection on June 11, 1979 the lake level was about 1 foot below the ground immediately downstream of the toe of the check dam.

The spillway consists of a concrete box culvert with six barrels, located under U.S. Highway 54. The spillway discharges into a channel which flows into the South Fork Salt River.

According to Mr. Durham, a representative of the Missouri Power and Light Company, an 8-inch flexible outlet pipe passes beneath the embankment to a pumphouse located just downstream of the dam. The inlet invert can be raised or lowered by a cable which is attached to a steel tower located in the reservoir. The intake of the pipe is protected by a strainer. The outlet is controlled by a globe valve located in the pumphouse. The pumphouse houses one electrically driven pump.

b. Location

C & A Lake Dam is located on a tributary to the South Fork Salt River in Audrain County, Missouri. The nearest community is Mexico, located less than one mile downstream from the dam. The dam and the lake are shown on the Mexico East, Missouri Quadrangle Sheet (7.5 minute series) in Section 25, Township 51 North, Range 9 West.

c. Size Classification

According to the "Recommended Guidelines for Safety Inspection of Dams", by the U.S. Department of the Army, Office of the Chief Engineer, the main dam is classified in the dam size category as being "Small" since its storage is less than 1,000 acre-feet. The main dam is also classified as "Small" in dam size category because its height is less than 40 feet. The overall size classification is, accordingly, "Small" in size. The check dam, which is three feet in height, does not fall in any dam category according to the criteria presented in the publication "Recommended Guidelines for Safety Inspection of Dams". However, the check dam forms a continuous barrier to the impoundment created by the main dam.

d. Hazard Classification

The C & A Lake Dam has been classified as having "Significant" hazard potential in the National Inventory of Dams, on the basis that in the event of failure of the dam or its appurtenances, appreciable damage could occur to downstream property, together with the possibility of the loss of life. Our findings concur with the classification. Within about three miles downstream of the main dam of C & A Lake are a railroad bridge, two highway bridges, a school, and a light duty road and bridge. The South Fork Salt River flows along the east edge of the community of Mexico.

e. Ownership

The check dam of C & A Lake is owned by the Missouri Power & Light Company. The mailing address is Missouri Power & Light Company, c/o Mr. Alberti, P.O. Box 190, Moberly, Missouri, 65270. The main dam (the railroad embankment) of C & A Lake is owned by the Illinois Central Gulf Railroad Company. The mailing address is IC&G Railroad Company, c/o Jan Wiley, Engineering Department, P.O. Box 880, Bloomington, Illinois, 61701.

f. Purpose of Dams

The purpose of the dams is to impound water to replenish losses from cooling towers belonging to the Missouri Power & Light Company. The main dam supports the Illinois Central Gulf and Burlington Northern railroad track.

g. Design and Construction History

It is not known specifically who designed the main and the check dam of C & A Lake. It is believed that the Chicago and Alton Railroad originally constructed the main dam. The check dam was constructed by the Missouri Power and Light Company. It was learned from officials at Missouri Power & Light Co. that the main dam and the surrounding property has changed ownership several times between railroad companies. The main dam of C & A Lake is now owned by the Illinois Central Gulf Railroad. Missouri Power & Light Co. bought the lake and part of the surrounding property from the Gulf, Mobile, and Ohio railroad in December, 1950.

h. Normal Operational Procedures

There are no set operational procedures for C & A Lake Dam. There is a small pumphouse facility which is, for the most part, out of service. The maintenance personnel periodically check the pumps to make certain they are operable. When the pumps are in use, their purpose is to pump water from C & A Lake to the South Fork Salt River for use at the Missouri Power & Light Co. Power Plant on the western end of the community of Mexico.

1.3        Pertinent Data

a.     Drainage Area (square miles):	2.92
b.     Discharge at Damsite	
Estimated experienced maximum flood (cfs):	N/A
Estimated ungated spillway capacity with reservoir at top of the check dam elevation (cfs):	515
c.     Elevation (Feet above MSL)	
Top of main dam:	754.8
Top of check dam:	743.3
Spillway crest:	
Service Spillway	741.0
Emergency Spillway	N/A
Normal Pool	741.0
Maximum Pool (PMF):	750.7
d.     Reservoir	
Length of pool with surface at top of dam elevation (feet):	3,200
e.     Storage (Acre-Feet)	
Top of main dam:	1,194
Top of check dam:	221
Spillway crest:	
Service Spillway	104
Emergency Spillway	N/A
Normal Pool:	104
Maximum Pool (PMF):	793
f.     Reservoir Surface (Acres)	
Top of main dam:	109

Top of check dam:	64
Spillway crest:	

Service Spillway	39
------------------	----

Emergency Spillway	N/A
--------------------	-----

g. Dams

Main Dam:

Type:	Earthfill
-------	-----------

Length:	900 feet
---------	----------

Structural Height:	27 feet
--------------------	---------

Hydraulic Height:	27 feet
-------------------	---------

Top width:	8.5 feet
------------	----------

Side slopes:

Downstream	1V to 1.5H
------------	------------

Upstream	1V to 1.5H
----------	------------

Zoning:	Unknown
---------	---------

Impervious core:	Unknown
------------------	---------

Cutoff:	Unknown
---------	---------

Grout curtain:	Unknown
----------------	---------

Check Dam:

Type:	Earthfill
-------	-----------

Length:	182 feet
---------	----------

Structural Height:	3 feet
--------------------	--------

Hydraulic Height:	3 feet
-------------------	--------

Top width:	4 feet
------------	--------

Side slopes:

Downstream	1V to 3H
------------	----------

Upstream	1V to 3H (From the crest to the water's edge)
----------	-----------------------------------------------

Zoning:	Unknown
---------	---------

Impervious core:	Unknown
------------------	---------

Cutoff:	Unknown
---------	---------

Grout curtain:	Unknown
----------------	---------

h. Diversion and Regulating Tunnel                          None

**i. Spillway**

**Type:**

Service Spillway	Box culvert with six barrels, uncontrolled
Emergency Spillway	None

**Length of crest:**

Service Spillway	47.91 feet
Emergency Spillway	N/A

**Crest Elevation (feet above MSL):**

Service Spillway	741
Emergency Spillway	N/A

**j. Regulating Outlets**

**Type:** 8-inch flexible water supply outlet pipe

**Length:** Unknown

**Closure:** Globe Valve

**Maximum Capacity:** Unknown

## SECTION 2 : ENGINEERING DATA

### 2.1        Design

No design drawings or data are available for the dams of C & A Lake. Information concerning the design of the dams was not available from the present owners, the Illinois-Central-Gulf Railroad, and the Missouri Power and Light Company.

### 2.2        Construction

The main dam was constructed by the Chicago & Alton Railroad. No construction records or as-built drawings were available. The source of the embankment materials is unknown, however, it is probable that soils within the immediate area of the dam were used.

The check dam was constructed by the Missouri Power and Light Company. No construction records or as-built drawings were available. The source of the embankment materials is unknown, however, it is likely that soils within the immediate area of the check dam were used.

### 2.3        Operation

No operation records are available for the C & A Lake Dam.

Evaluation

## a. Availability

No design drawings, design computations, construction data, or operation data are available.

In addition, no pertinent data were available for review of hydrology, spillway capacity, flood routing through the reservoir, slope stability, seepage analysis, or foundation conditions.

## b. Adequacy

The lack of engineering data did not allow for a definitive review and evaluation. Therefore, the adequacy of this dam could not be assessed from the standpoint of reviewing and evaluating design, operation and construction data, but is based primarily on visual inspection, past performance history, and sound engineering judgment.

Seepage and stability analyses comparable to the requirements of "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

## c. Validity

No valid engineering data are available.

### SECTION 3: VISUAL INSPECTION

#### 3.1      Findings

##### a. General

A visual inspection of the check dam of C & A Lake was made on June 11, 1979. The following persons were present during the inspection:

Name	Affiliation	Disciplines
David J. Kerkes	Engineering Consultants, Inc.	Soils
Peter Howard	Engineering Consultants, Inc.	Geology
Mark R. Haynes	Engineering Consultants, Inc.	Civil, Structural and Mechanical
Kenneth L. Bullard	Engineering Consultants, Inc.	Hydraulics and Hydrology
Kevin Blume	Consoer, Townsend & Assoc., Ltd.	Civil and Structural
John Ziegler	Missouri Power & Light Co.	
Clay Durham	Missouri Power & Light Co.	

The visual inspection of the main dam (the railroad embankment) of C & A Lake was made on October 13, 1979. The following persons were present during the inspection:

Name	Affiliation	Disciplines
Dr. M.A. Samad	Engineering Consultants, Inc.	Project Engineer, Hydraulics and Hydrology
Mark R. Haynes	Engineering Consultants, Inc.	Civil, Structural and Mechanical
Kevin Blume	Consoer, Townsend & Assoc., Ltd.	Civil and Structural

Specific observations are discussed below.

b. Dam

(1) Main Dam

The railroad track on top of the main dam is placed upon a typical railroad ballast embankment. The top of the rails are approximately 18 inches above the main embankment of the dam. The crest of the main embankment varies in width from 15 to 30 feet while the ballast embankment for the track is only 8.5 feet wide. Therefore, a bench has been formed on top of the main embankment. The ballast embankment starts approximately 2 feet upstream from the crest of the downstream slope of the main embankment. The crest of the main embankment has no vegetative cover, however, it is adequately

protected by cinders. No evidence of settlement was observed along the crest. No cracks were observed.

Both the upstream and downstream slopes are overgrown with large trees and bushes. Both slopes are superficially covered by cinders and the gravel used for ballast.

The upstream slope has no riprap protection and consequently, some erosion, due to wave action, has occurred near the water surface. The slope has been steepened to near vertical for approximately 3 feet above the water surface and a small bench has been formed. No other erosion was observed on the slope. In a few places along the embankment no vegetative cover was observed, which appeared to be due to pedestrian traffic. No signs of instability or distress was observed on the slope. There were no cracks observed on the slope.

No seepage was observed along the toe. Several paths were observed on the embankment through the trees and bushes. There were no indications of past or present slope instability. There were no cracks observed on the slope.

The South Fork Salt River meanders to within 30 feet of the toe of the embankment at one point.

The right abutment is at the same elevation as the crest of the dam and the railroad track on the dam embankment continue out onto the abutment. The left abutment supports one of the abutments for the railroad bridge which crosses over U.S. Highway 54 and the South Fork Salt River. Neither abutment showed signs of instability.

No signs of rodent activity were observed in either the embankment or the abutments.

No rock outcrops were apparent in the vicinity of the dam.

(2) Check Dam

The crest of the check dam has a short cover of grass in most places. Some settlement was observed in several locations, however, no cracks were visible. No significant deviations in horizontal or vertical alignment were apparent. According to Mr. Ziegler the embankment has been overtopped in 1973, however, the incident occurred as a result of flooding of the South Fork Salt River. Waters overtopped the dam from the downstream side and flooded into C & A Lake. According to Mr. Ziegler, however, the dam was not washed out, to the best of his knowledge.

The upstream slope is covered in most areas by bushes and grass. There is essentially no riprap. The slope is quite irregular with evidence of erosion in several areas. It was not possible to determine to what degree the condition of the slope was affected by pedestrian traffic, however, there were no readily apparent signs of sloughing or slope instability. There were no cracks observed on the slope.

The downstream slope has a well maintained cover of grass with no signs of erosion. There were no trees or bushes growing on the slope. A small depression was apparent in one area near the right abutment which may be related to past minor sloughing. There were no other indications of past or present slope instability. There were no cracks observed in the downstream slope. No seepage was observed along the toe.

Field measurement indicated that the lake was about 1 foot below the ground downstream of the dam on the day of the inspection.

No erosion was observed at either abutment contact, nor was seepage observed. No cracking was observed along embankment abutment contacts.

No signs of rodent activity were observed in either the embankment or the abutments.

No data are available indicating the type of material used for construction of the embankment. Material taken from below the topsoil on the embankment was a fine sandy clay.

According to the "Missouri General Soil Map and Soil Association Description" published by the Soil Conservation Service, the materials in the general area of the dam belong to the soil series of Mexico-Leonard-Armstrong-Lindley in the Central Claypan Area. These soils are deep, nearly level to steep, well drained to somewhat poorly drained, loamy and clayey upland soils.

#### c. Project Geology

The dams are located in the Dissected Till Plain physiographic province (Fenneman, N.M., "Physiography of Eastern United States", 1946). This area was glaciated during Pleistocene time, at the close of which relatively thick deposits of glacial till were left.

Regionally, the area ranges in age from Ordovician to Pennsylvanian and dips gently (about 40 feet per mile) to the northeast off of the Ozark Uplift to the south. The bedrock underlying the site is composed of cyclic deposits, predominately sandstone and shale, of the Cabiness subgroup (Pennsylvanian) [Geologic Map of Missouri, 1979].

d. Appurtenant Structures

(1) Spillway

The spillway consists of a concrete box culvert with six barrels, located under U.S. Highway 54. Some minor spalling was observed along with minor cracks at the top of a few walls. No reinforcement was exposed. There was no apparent displacement of joints. Some joint material was extruding from the joint between the last barrel on the north and south end of the spillway and the wingwalls. A small amount of undercutting has taken place on the right side, as viewed from upstream, of the spillway. The last barrel on the left side is covered in large part by bushes.

(2) Outlet Works

The outlet works consist of an 8-inch diameter flexible pipe connected to a pump located immediately downstream of the check dam in a wooden pumphouse. The intake is reported to have a strainer over it according to Mr. Durham. Mr. Durham stated that the pump was last operated in March 1979. According to Mr. Durham, the pump is not normally used more than twice a year. The intake to the outlet works was not accessible at the time of the inspection.

e. Reservoir Area

The water surface elevation was 739.3 feet above MSL on the day of the inspection (June 11, 1979).

The slopes along the reservoir rim are gentle with good grass protection. No evidence of past or present instability of the slopes was readily apparent.

e. Downstream Channel

The downstream channel is broad and well defined, however, it is heavily overgrown by trees and bushes. No significant erosion was observed. The channel joins the South Fork Salt River in a short distance.

3.2 Evaluation

The visual inspection did not reveal any conditions which were felt to pose an immediate threat to the safety of the structure, however, certain deficiencies do exist which warrant attention. The deficiencies which could affect the safety of the dams or which will require maintenance within a reasonable period of time are discussed in Section 7.2.

## SECTION 4: OPERATIONAL PROCEDURES

### 4.1 Procedures

There are no specific operational procedures at this time for C & A Lake Dam. As stated in Section 1.2h, occasionally water is pumped from C & A Lake to the South Fork Salt River to eventually be used as cooling water for Missouri Power & Light Co.

### 4.2 Maintenance of Dam

The main dam is used by IC&G Railroad. A minimum amount of maintenance is performed on the dam. When maintenance is done on the dam, it is done by personnel from the IC&G Railroad. The check dam is maintained by Missouri Power and Light maintenance crews.

### 4.3 Maintenance of Operating Facilities

The only operating facility located at the damsite is a centrifugal pump with two main globe (angle) valves. The pump was test run last March, 1979. The valves, which are connected to the intake and discharge lines, are operable and maintained by Missouri Power & Light maintenance crews.

Little maintenance is provided on the pump and valves since the water supply line is not used very often.

4.4        Description of Any Warning System in Effect

The inspection teams are not aware of any existing warning system in effect.

4.5        Evaluation

It appears that the railroad maintenance crews keep the crest of the main dam adequately protected with ballast and cinders. There are, however, several areas where wave action has caused erosion on the upstream slope. Many trees combined with dense vegetation cover both the upstream and downstream slopes. Generally speaking, the maintenance for the main dam is less than adequate.

While the crest and downstream slope of the check dam appear to be adequately maintained more attention should be given to the condition of the upstream slope. The vegetation growing in the downstream channel and over the spillway inlet should also be controlled. The undercutting of the spillway should be repaired.

## SECTION 5: HYDRAULIC/HYDROLOGIC

### 5.1 Evaluation of Features

#### a. Design

The watershed area of the C & A Lake Dam consists of approximately 1,870 acres. The watershed area is in meadow with some woods and farmland, and some residential development. Land gradients in the watershed average roughly 1 percent. The C & A Lake Dam is located on an unnamed tributary of South Fork Salt River. The reservoir is about 300 feet upstream from the confluence of the unnamed tributary and South Fork Salt River. At its longest arm the watershed is approximately 2-1/4 miles long. A drainage map showing the watershed is presented as Plate 1 in Appendix B.

Evaluation of the hydraulic and hydrologic features of C & A Lake Dam was based on criteria set forth in the Corps of Engineers' "Recommended Guidelines for Safety Inspection of Dams", and additional guidance provided by the St. Louis District of the Corps of Engineers. The Probable Maximum Flood (PMF) was calculated from the Probable Maximum Precipitation (PMP) using the methods outlined in the U.S. Weather Bureau Publication, Hydrometeorological Report No. 33. The probable maximum storm duration was set at 24 hours, and storm rainfall distribution was based on criteria given in the Corps of Engineers' EM 1110-2-1411 (Standard Project Storm). The Soil Conservation Service (SCS) method was used for deriving the unit hydrograph, utilizing the Corps of Engineers' computer program HEC-1 (Dam Safety Version). The unit hydrograph

parameters are presented in Appendix B. The SCS method was also used for determining the loss rate. The hydrologic soil group of the watershed was determined by use of published soil maps. The hydrologic soil group of the watershed and the SCS curve number are presented in Appendix B. The curve number, the unit hydrograph parameters, the PMP index rainfall and the percentages for various durations were directly input to the HEC-1 (Dam Safety Version) computer program to obtain the PMF hydrograph. The computed peak discharges of the PMF and one-half of the PMF are 16,650 cfs and 8,325 cfs, respectively.

Both the PMF and one-half of the PMF hydrographs were routed through the reservoir by the Modified Puls Method also utilizing the HEC-1 (Dam Safety Version) computer program. The reservoir was assumed at the spillway crest level at the start of the routing computation. The peak outflow discharges for the PMF and one-half of the PMF are 15,584 and 6,971 cfs, respectively. Both the PMF and one-half of the PMF when routed through the reservoir resulted in overtopping of the check dam. However, neither one-half of the PMF nor the PMF overtopped the main dam.

From USGS Quadrangle and inventory of dams, we can see three lakes, one railroad embankment and one state highway located upstream of C & A Lake Dam. These upstream structures and embankments, which obviously have significant impact on the time and magnitude of the flood crest at the check dam site, should be included in the system HEC-1 (Dam Safety Version) model to more reasonably evaluate the spillway capacity for the dam.

The size of physical features utilized to develop the stage-outflow relation for the spillway and overtopping of the dams were determined from field notes, and sketches, prepared during the field inspections. The reservoir stage-capacity data were based on the U.S.G.S. Mexico East, Missouri Quadrangle topographic map (7.5 minute series). The spillway and dam overtop rating curve and the reservoir capacity curve are presented as Plates 2 & 3, respectively, in Appendix B.

From the standpoint of dam safety, the hydrologic design of a dam must aim at avoiding overtopping. Overtopping is especially dangerous for an earth dam because of its erodible characteristics. The safe hydrologic design of an embankment dam requires a spillway discharge capability, in combination with an embankment crest height that can handle a very large and exceedingly rare flood without dam overtopping.

The Corps of Engineers design dams to safely pass the Probable Maximum Flood that is estimated could be generated from the dam's watershed. This is the generally accepted criterion for major dams throughout the world, and is the standard for dam safety where overtopping would pose any threat to human life. Although dams that do not fully meet this standard will not be evaluated as "unsafe", any dam located in a "Significant" hazard potential area should be considered to be seriously inadequate if it can not pass the 100-year flood without overtopping.

#### b. Experience Data

It is believed that no records of reservoir stage or spillway discharge are maintained for this site.

c. Visual Observations

Observations made of the spillway during the visual inspection are discussed in Section 3.1c(1) and evaluated in Section 3.2.

d. Overtopping Potential

As indicated in Section 5.1.a, both the Probable Maximum Flood and one-half of the Probable Maximum Flood, when routed through the reservoir, resulted in overtopping of the check dam of C & A Lake. However, the main dam (the railroad embankment) was not overtopped by the PMF or one-half of the PMF. The peak outflow discharges for the PMF and one-half of the PMF are 15,584 and 6,971 cfs, respectively. The PMF overtopped the check dam by 7.40 feet and one-half of the PMF overtopped the check dam by 4.92 feet. The total duration of embankment overflow is 16.33 hours during the PMF and 11.67 hours during one-half of the PMF. The spillway/reservoir system of C & A Lake Dam is capable of accommodating a flood equal to approximately 6 percent of the PMF before overtopping the check dam. Our evaluation also indicates that the spillway/reservoir system of C & A Lake Dam will not accommodate the 10-year flood without overtopping the check dam.

The failure of the check dam during the occurrence of the PMF could cause appreciable damage to the property downstream of the dam and possible loss of life. Within about three miles downstream from the dam are two highway bridges, one railroad bridge, a school, and a light duty road and bridge.

## SECTION 6: STRUCTURAL STABILITY

6.1

### Evaluation of Structural Stability

#### a. Visual Observations

##### (1) Main Dam

The erosion of the upstream slope due to wave action could jeopardize the structural stability of the dam if it is allowed to continue. No other indications of past or present slope instability were observed. In the absence of seepage and stability analyses, no quantitative evaluation of the structural stability can be made.

##### (2) Check Dam and Spillway

A small depression was apparent in the downstream slope near the right abutment which may be related to past minor sloughing. The upstream slope is quite irregular with evidence of erosion in several areas. There were no other indications of past or present slope instability.

Some undercutting of the spillway was observed, however, it does not pose an immediate threat to the structure at this time.

b. Design and Construction Data

No design computations were uncovered during the report preparation phase. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available. No embankment or foundation soil parameters are available for carrying out a conventional stability analysis on the embankments. No construction data or specifications relating to the degree of embankment compaction are available for use in a stability analysis.

c. Operating Records

No operating records are available relating to the stability of the dam. According to the owner's representative of the check dam, the check dam has served satisfactorily since it was constructed with no history of problems, to the best of his knowledge.

d. Post Construction Changes

There are no records of post-construction changes for the main or the check dam of C & A Lake.

e. Seismic Stability

The dams are located in Seismic Zone 1, as defined in "Recommended Guidelines For Safety Inspection of Dams" as prepared by the Corps of Engineers. The engineer performing the stability analysis on the embankment shall determine the necessity of a seismic analysis for this embankment.

## SECTION 7: ASSESSMENT/REMEDIAL MEASURES

### 7.1 Dam Assessment

The assessment of the general condition of the dams of C & A Lake are based upon available data and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation, however, the investigation is intended to identify any need for such studies.

It should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team.

It is also important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dams will continue to represent the condition of the dams at some point in the future. Only through continued care and inspection can there be assurance that an unsafe condition could be detected.

#### a. Safety

The spillway capacity of C & A Lake Dam was found to be "Seriously Inadequate". The spillway/reservoir system can accommodate only 6 percent of the PMF without overtopping the check dam. The spillway and the reservoir will not even accommodate the 10-year flood without overtopping the check dam. The check dam is overtopped by over seven feet during

the PMF and the duration of emankment overflow is over sixteen hours. In addition, an event equal to 50 percent of the PMF overtops the dam by about 5 feet with an overflow duration of over eleven hours. Overtopping of the check dam by such magnitude and duration may cause failure of the check dam.

No quantitative evaluation of the safety of the embankments can be made in view of the absence of seepage and stability analyses. The present embankments, however, appear to have performed satisfactorily since their construction without failure or evidence of instability. The check dam reportedly was overtopped from the downstream side and no evidence was observed of the main dam ever being overtopped.

The erosion due to wave action on the upstream slope of both the main and the check dams, if allowed to continue, could jeopardize the safety of the dams. Therefore, the eroded areas should be repaired and the slopes protected from further damage.

b. Adequacy of Information

Pertinent information relating to the design and construction of the dams is lacking. The conclusions presented in this report are based on the available engineering data, past performance and present condition of the dams. No information on the design hydrology, hydraulic design, and the operation and maintenance of the dams, as well as seepage and stability analyses were available for review.

c. Urgency

The remedial measures recommended in Paragraph 7.2 should be accomplished within a reasonable period of time. The items recommended in paragraph 7.2.a should be pursued without delay.

d. Necessity for Phase II Inspection

Based on results of the Phase I inspection, and if the remedial measures recommended in Paragraph 7.2 are undertaken, a Phase II inspection is not felt necessary.

7.2 Remedial Measures

a. Alternatives:

1. Spillway capacity and/or height of the check dam should be increased to pass one-half of the PMF without overtopping the check dam.

b. O & M Procedures

1. The upstream slope of the main dam should be cleared of all vegetation, regraded and properly riprapped.
2. The depressions observed on the crest of the check dam did not appear to indicate an instability of the embankment. Nevertheless, the depressions should be filled in and the areas protected from surface erosion.

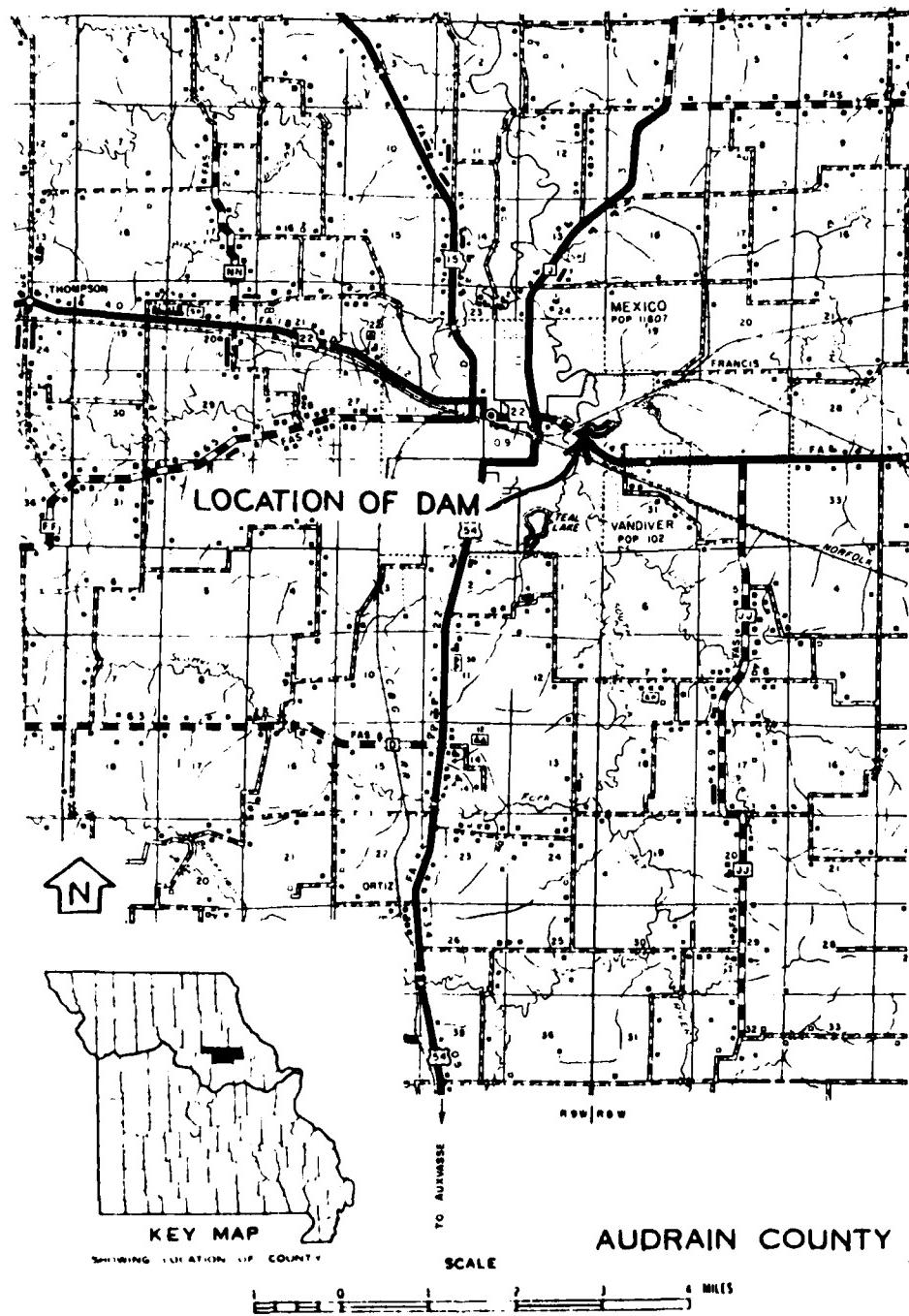
3. The downstream channel should be cleared of all vegetation.
4. Undercutting of the spillway should be repaired. The undercutting of the spillway not only jeopardizes the safety of the spillway, but also the safety of U.S. Highway 54 which passes over it. Therefore, the hole caused by the undercutting should be properly backfilled and protected from further damage due to discharge through the spillway.
5. The trees and bushes on both the upstream and downstream slopes of the main dam should be removed from the slopes and an adequate protective cover retained on the slopes. The removal of large trees should be accomplished under guidance of an engineer experienced in the design and construction of earthen dams. Indiscriminate clearing could jeopardize the safety of the embankment.
6. Seepage and stability analyses should be performed by a professional engineer experienced in the design and construction of dams.

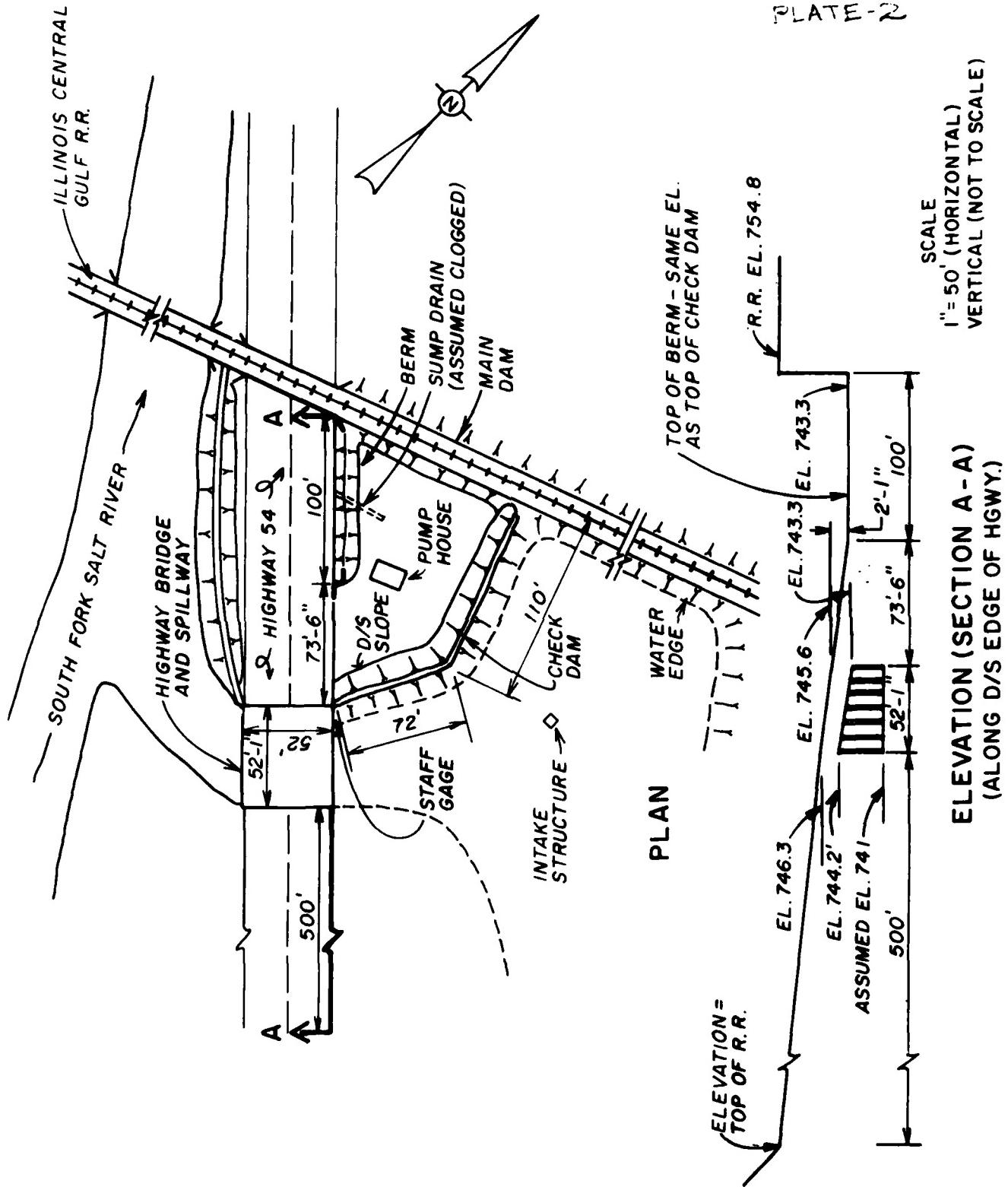
The owner should initiate the following programs:

1. Periodic inspection of the dam by a professional engineer experienced in the design and construction of earthen dams.
2. Set up a maintenance schedule and log all visits to the dam for operation, repairs and maintenance.

**PLATES**

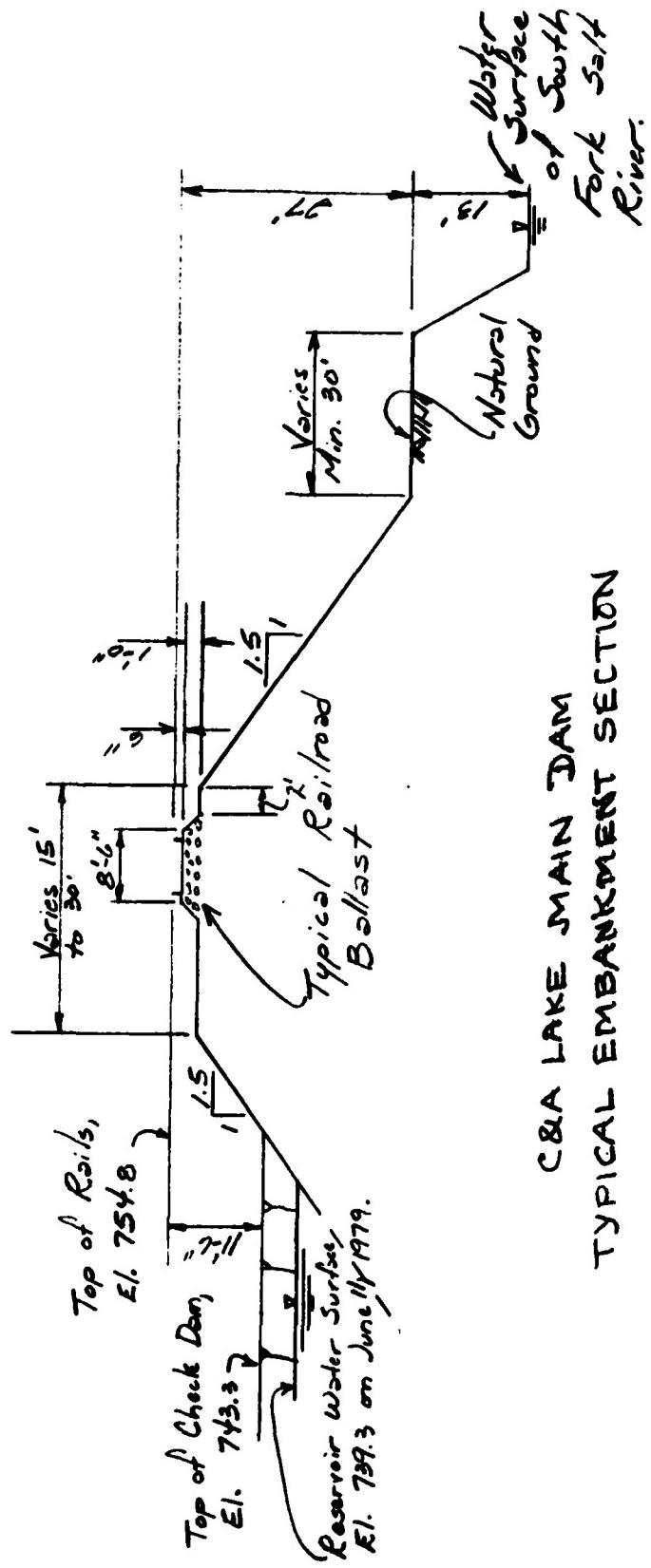
PLATE-1

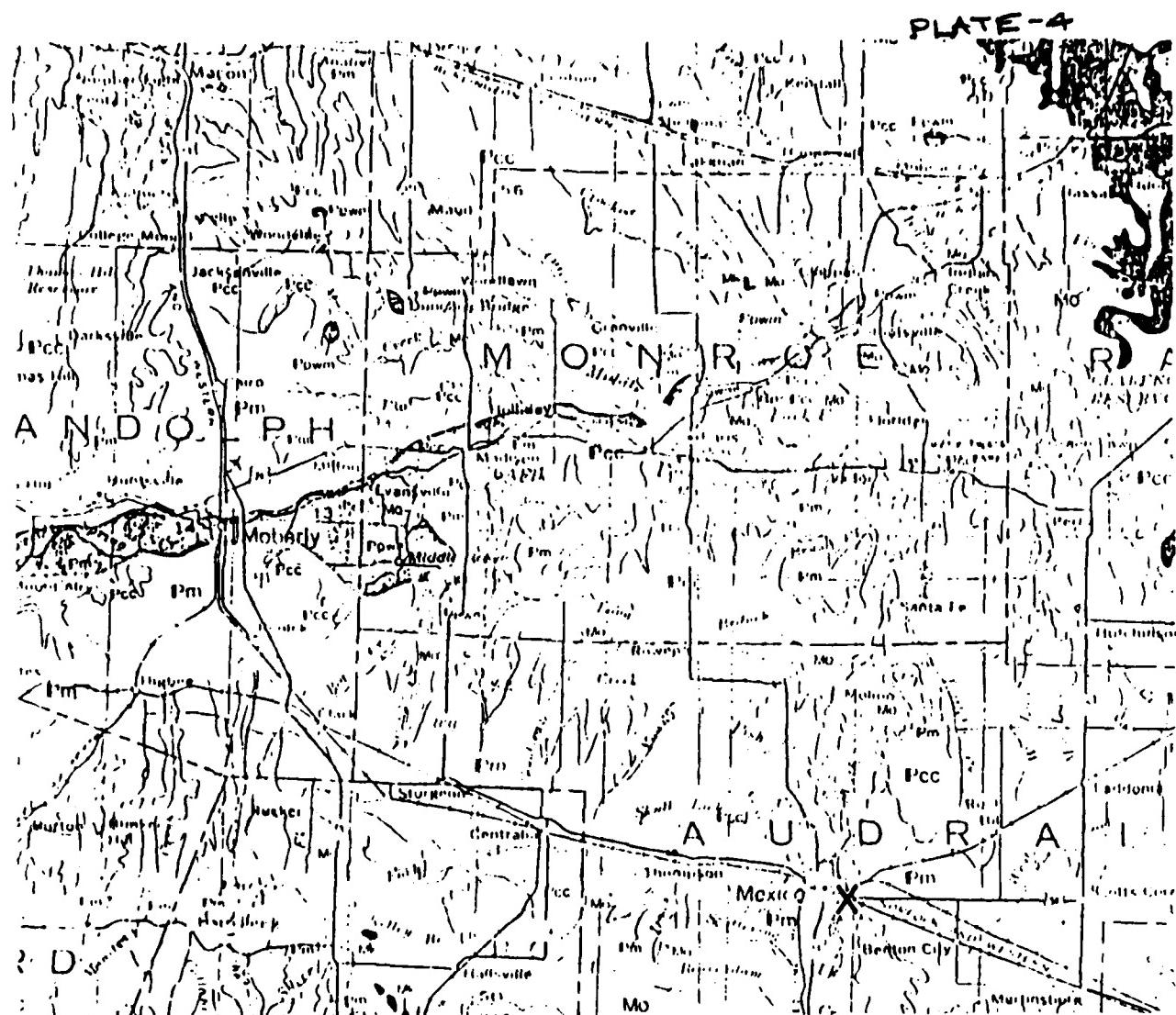




**C & A LAKE DAM (MO. 10105)  
PLAN & ELEVATION**

PLATE-3





PENNSYLVANIAN

Rp - PLEASANTON GROUP  
Rpw - WARRENSBURG - MOBERLY SANDSTONE

Rm - MARMATON GROUP

Rcc - CHEROKEE GROUP

Mm - MERAMACIAN SERIES

MISSISSIPPIAN

Mo - OSAGIAN SERIES

Mk - KINDERHOOKIAN SERIES

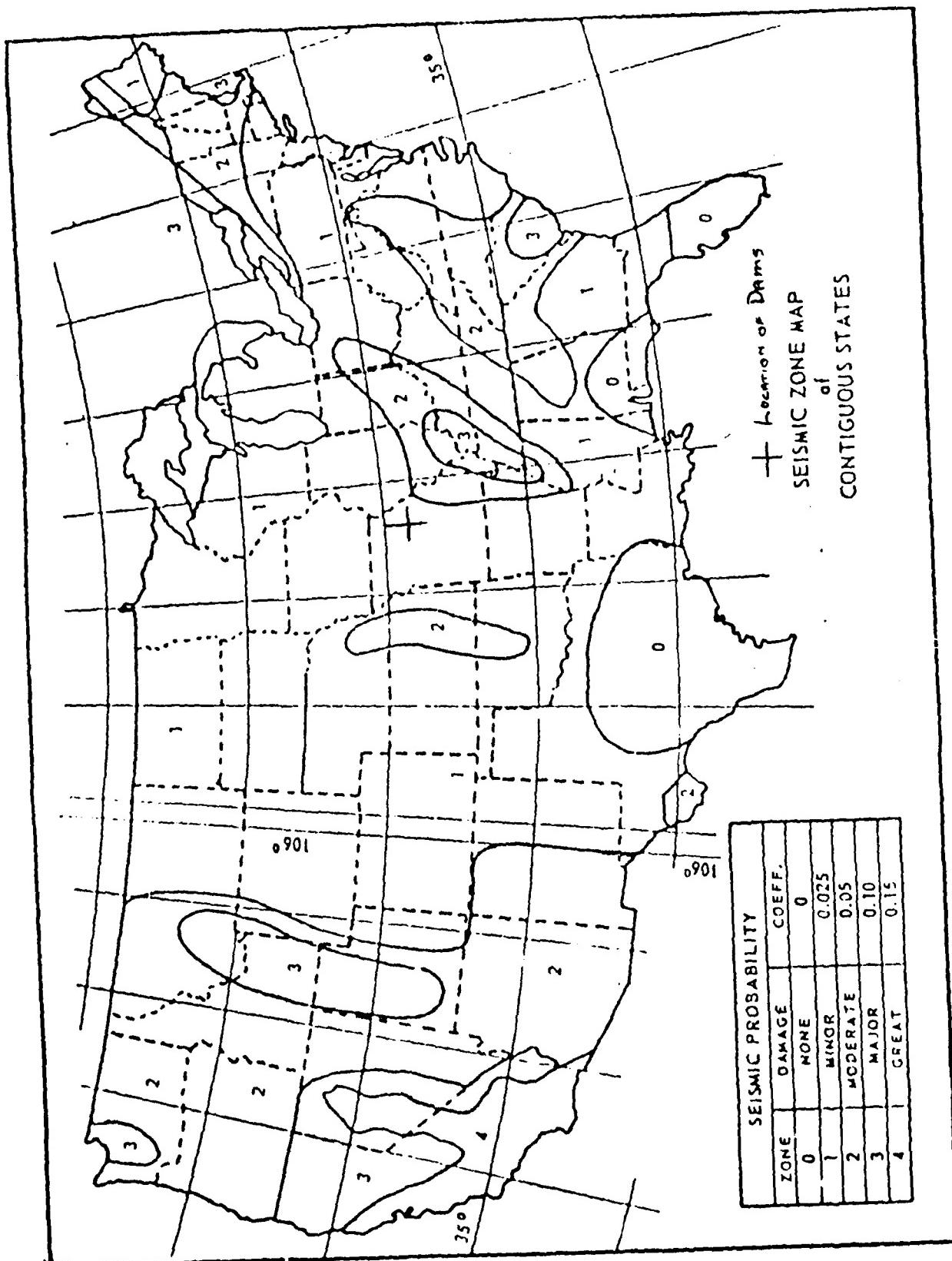
X - LOCATION OF DAMS, MO. 10105

REFERENCE:

GEOLOGIC MAP OF MISSOURI,  
MISSOURI GEOLOGIC SURVEY,  
a) 1961; b) 1979

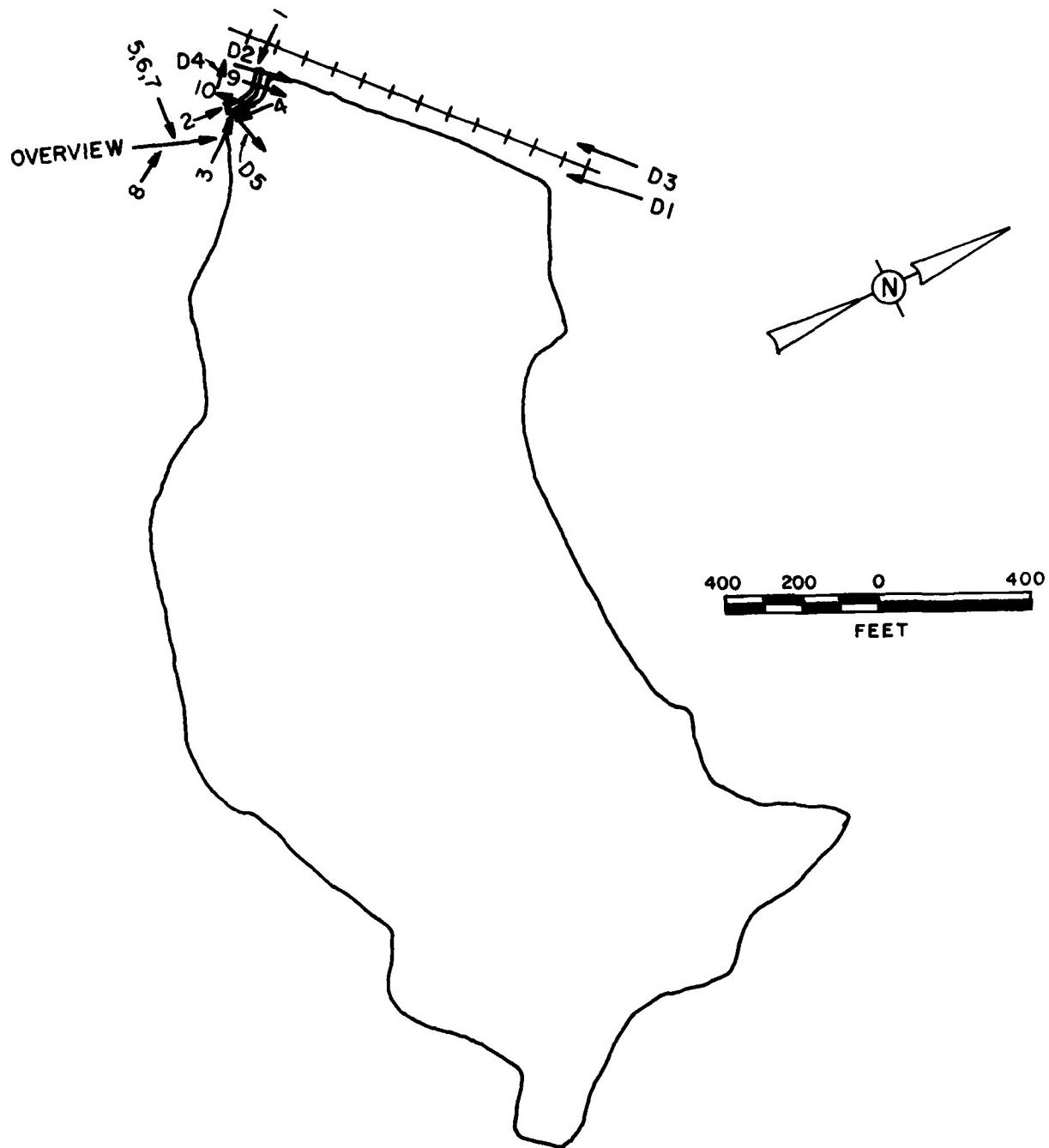
GEOLOGIC MAP  
OF  
MONROE COUNTY  
AND  
ADJACENT AREA

PLATE-5



APPENDIX A

PHOTOGRAPHS TAKEN DURING INSPECTION



400 200 0 400  
FEET

PHOTO INDEX  
FOR  
C & A LAKE DAM

C & A LAKE DAM

Main Dam

- Photo D1 - View of the crest.
- Photo D2 - View of the upstream embankment slope.
- Photo D3 - View of the downstream embankment slope.
- Photo D4 - View of the railroad bridge over U.S. Highway 54.
- Photo D5 - View of reservoir rim.

Check Dam

- Photo 1. - View of the crest and the downstream embankment slope.
- Photo 2. - View of the crest and the downstream embankment slope.
- Photo 3. - View of the upstream embankment slope. Note the pump house.
- Photo 4. - View of the intake of the spillway.
- Photo 5. - View of the spillway discharge channel.
- Photo 6. - View of the outlet of the spillway.
- Photo 7. - View of the outlet of the spillway.
- Photo 8. - View of the undermining of the outlet of the spillway. Note, the floor of the spillway is at the bottom of the pipe.
- Photo 9. - View of the intake control structure and the reservoir rim.
- Photo 10. - View of the pump.

**MAIN DAM**



Photo D1 - View of the crest.



Photo D2 - View of the upstream embankment slope.



Photo D3 - View of the downstream embankment slope.



Photo D4 - View of the railroad bridge over U.S. Highway 54.

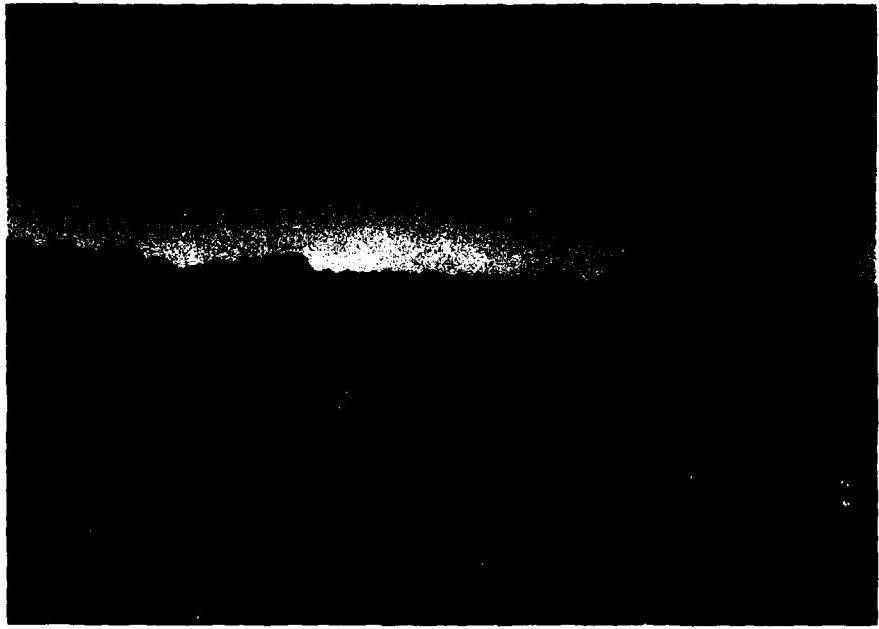


Photo D5 - View of reservoir rim.

**CHECK DAM**

C & A Lake Dam



Photo 1



Photo 2

C & A Lake Dam



Photo 3



Photo 4

C & A Lake Dam

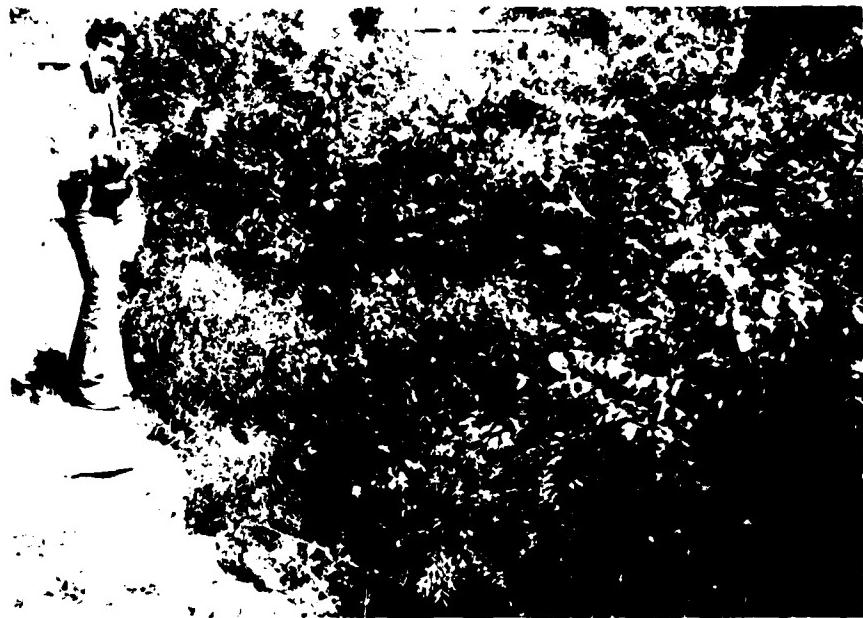


Photo 5



Photo 6

C & A Lake Dam



Photo 8

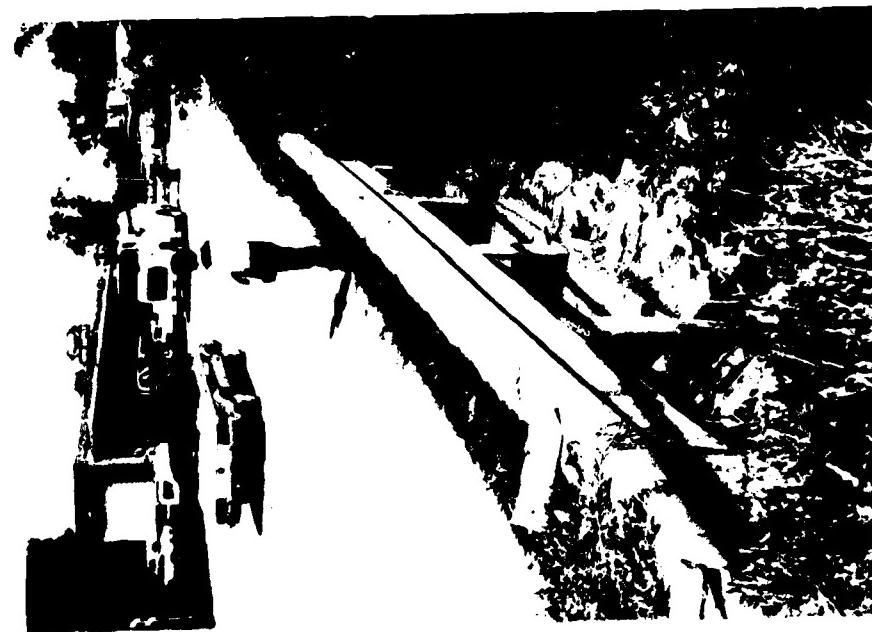


Photo 7

C & A Lake Dam



Photo 9

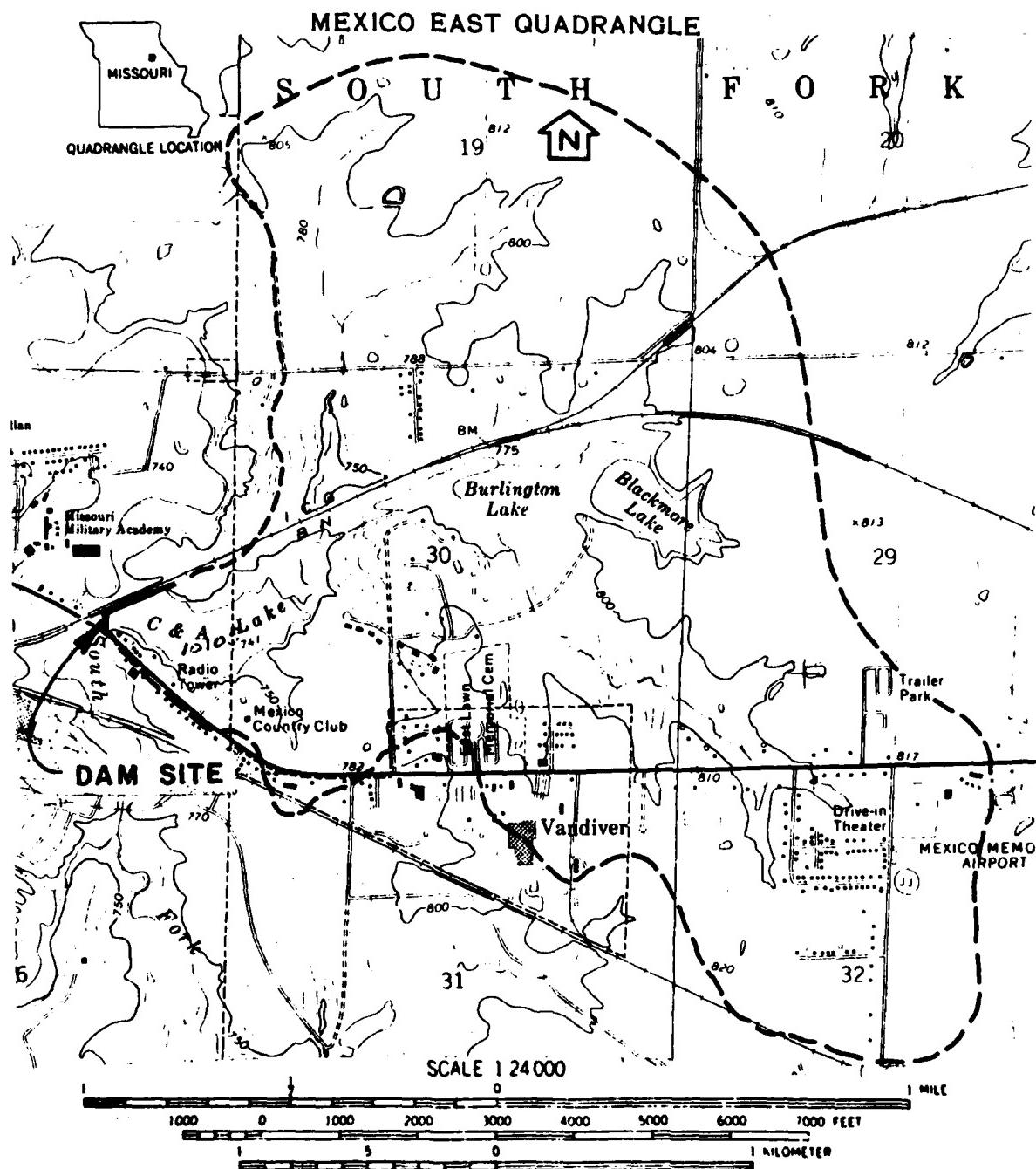


Photo 10

APPENDIX B  
HYDROLOGIC COMPUTATIONS

B-1

PLATE 1, APPENDIX B



B-2



ECI-4 PRC ENGINEERING CONSULTANTS, INC.

DAM SAFETY INSPECTION - MISSOURI

SHEET NO. 2 OF 2

C&A LAKE DAM Mo. 10105

JOB NO. 1240

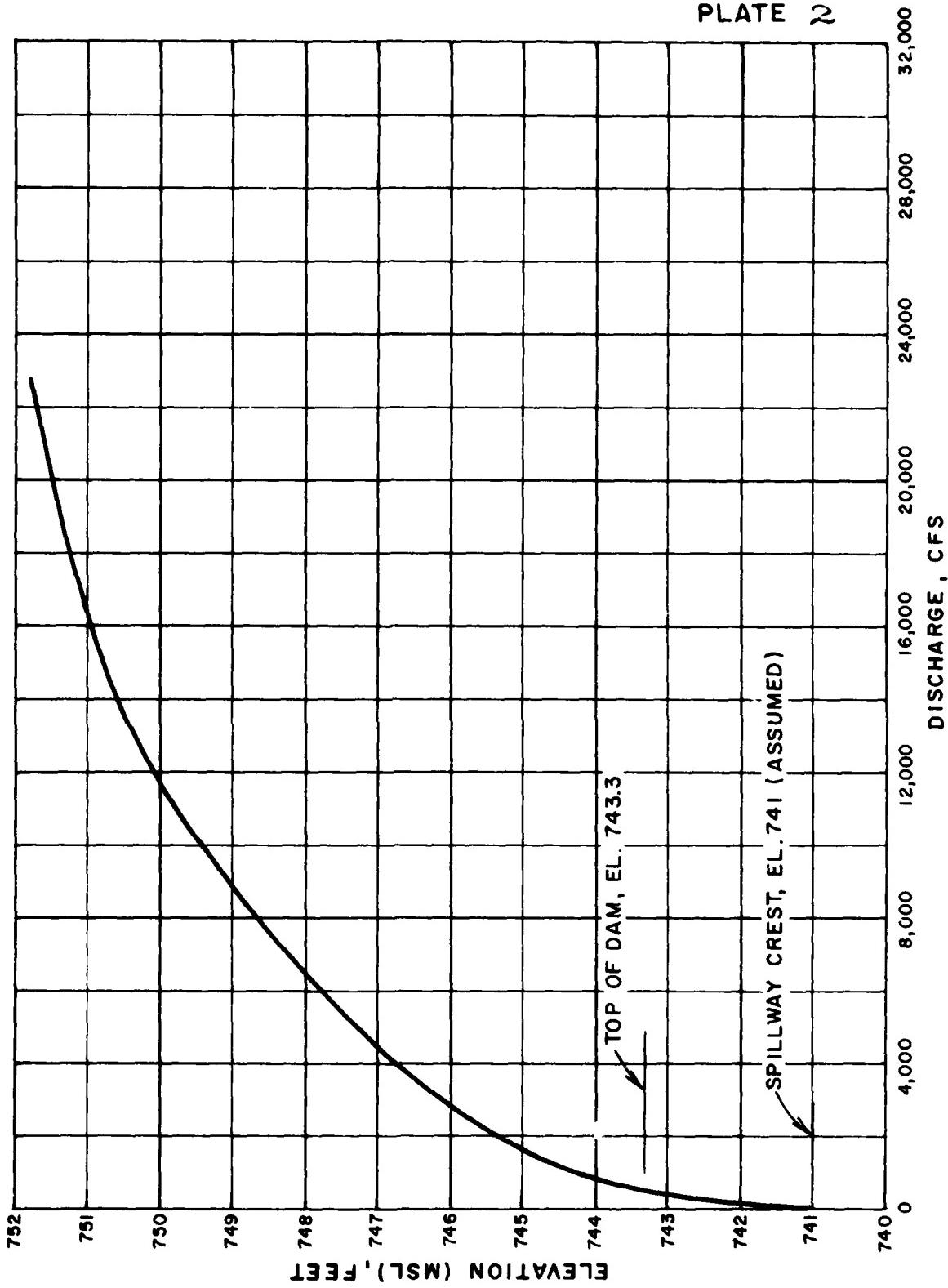
SPILLWAY AND OVERTOP RATING

BY PW DATE 10-23

C & A LAKE Dam

RESERVOIR Elevation	$Q_w = C_w V_w^{3/2}$ (WEIR FLOW)	$Q_p = 625 \sqrt{H_p}$ (PRESSURE HEAD)	$Q_{c1} = P_{c1} V_{c1}$	$Q_{c2} = C_{c2} H_{c2}^{3/2}$	$Q_{c3} = P_{c3} V_{c3}$		$Q_t = Q_p + Q_{c1} + Q_{c2} + Q_{c3}$
741	0						0
742	149		0				149
743	418		0				418
743.3	515		0				515
744.6	908		70	376	0		1354
745.8		1152	397	1044	44	0	2597
747.3		1383	1135	2112	231	48.3	4909
748.8		1581	2113	3405	744	425	8268
750.3		1757	3273	4860	1421	1369	12680
751.8		1916	4590	6511	2229	8378	23624

PLATE 2



C & A LAKE DAM (M.O. 10105)  
SPILLWAY & OVERTOP RATING CURVE

## ENGINEERING CONSULTANTS, INC.

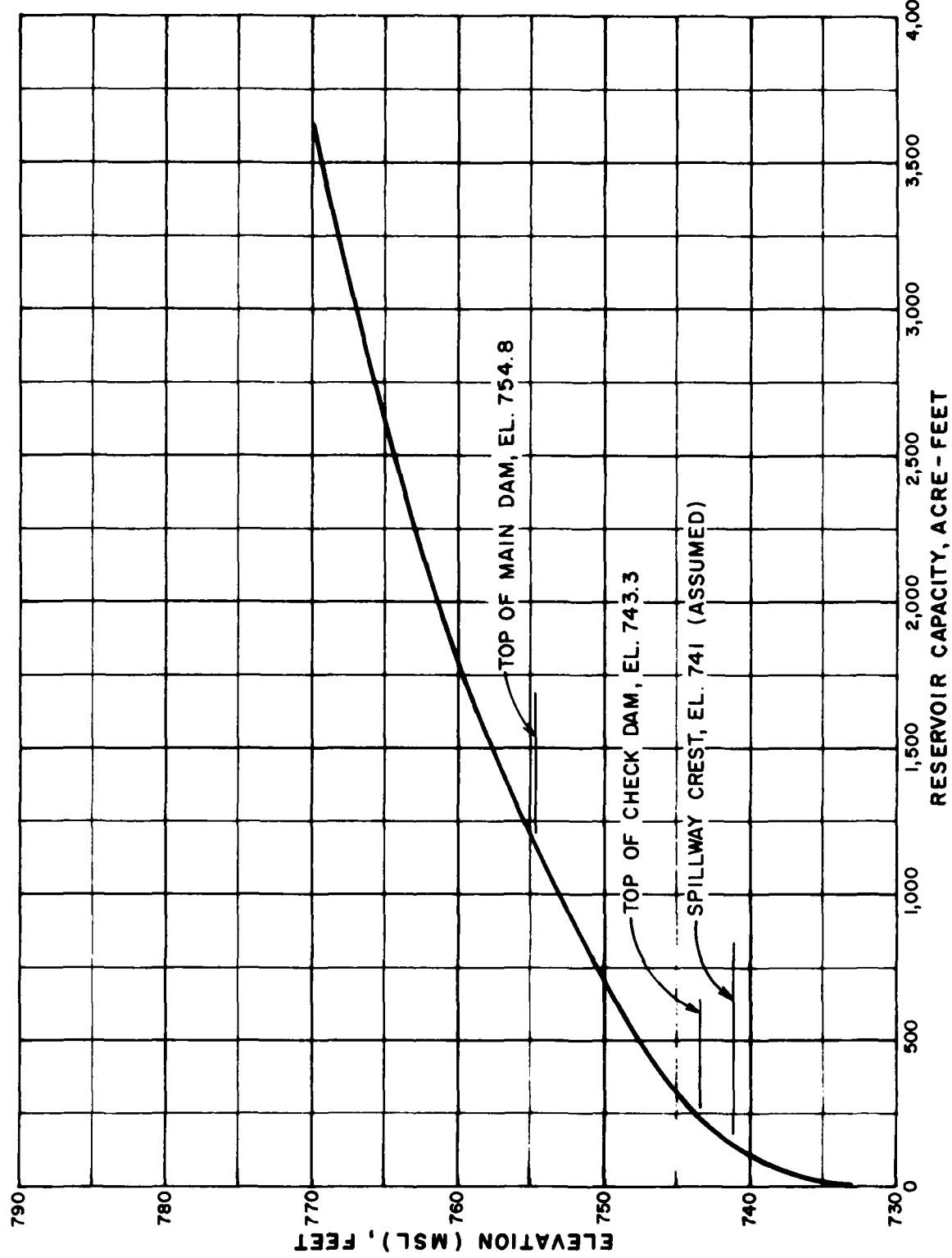
DAM SAFETY INSPECTION - MISSOURI SHEET NO. 1 OF  
 C+A LAKE DAM # 10105 JOB NO. 1240  
 RESERVOIR AREA CAPACITY BY D.N.Z. DATE  
*M.R.H.*

## C+A LAKE DAM

## RESERVOIR AREA CAPACITY

ELEV. MSL (ft)	RESERVOIR SURFACE AREA (ACRES)	INCREMENTAL VOLUME (AC-ft)	TOTAL VOLUME (AC-ft)	REMARKS
733	0	0	0	Est. Streambed Elev. at Dam
741	39	104	104	U.S. as shown on U.S.G.S. maps (Elev. Known) ASSUMED SPILLWAY CREST EL.
743.3	69	117	221	TOP OF CHECK Dam
750	87	504	725	AREA MEASURED ON U.S.G.S. MAP
754.8	109	469	1194	TOP OF MAIN Dam
760	132	625	1821	AREA MEASURED ON U.S.G.S. MAP
770	242	1842	3663	AREA MEASURED ON U.S.G.S. MAP

PLATE 3, APPENDIX B



C & A LAKE DAM (MO. 10105)  
RESERVOIR CAPACITY CURVE

## ECI-4 ENGINEERING CONSULTANTS, INC.

DAM SAFETY INSPECTION - MISSOURI  
C&A LAKE DAM # MO. 10105

SHEET NO. 1 OF \_\_\_\_\_

JOB NO. 1240

PROBABLE MAXIMUM PRECIPITATION BY DNZ DATE 6/11/79

0423

C&amp;A LAKE DAMS# MO. 10105

## DETERMINATION OF PMP

1. DETERMINE DRAINAGE AREA OF BASIN

$$D.A. = 1870 \text{ ACRES} = 2.92 \text{ Sq. mi.}$$

2. DETERMINE PMP INDEX RAINFALL (200 SQ. MI. + 24 HRS. DUR.)

## LOCATION OF CENTROID BASIN

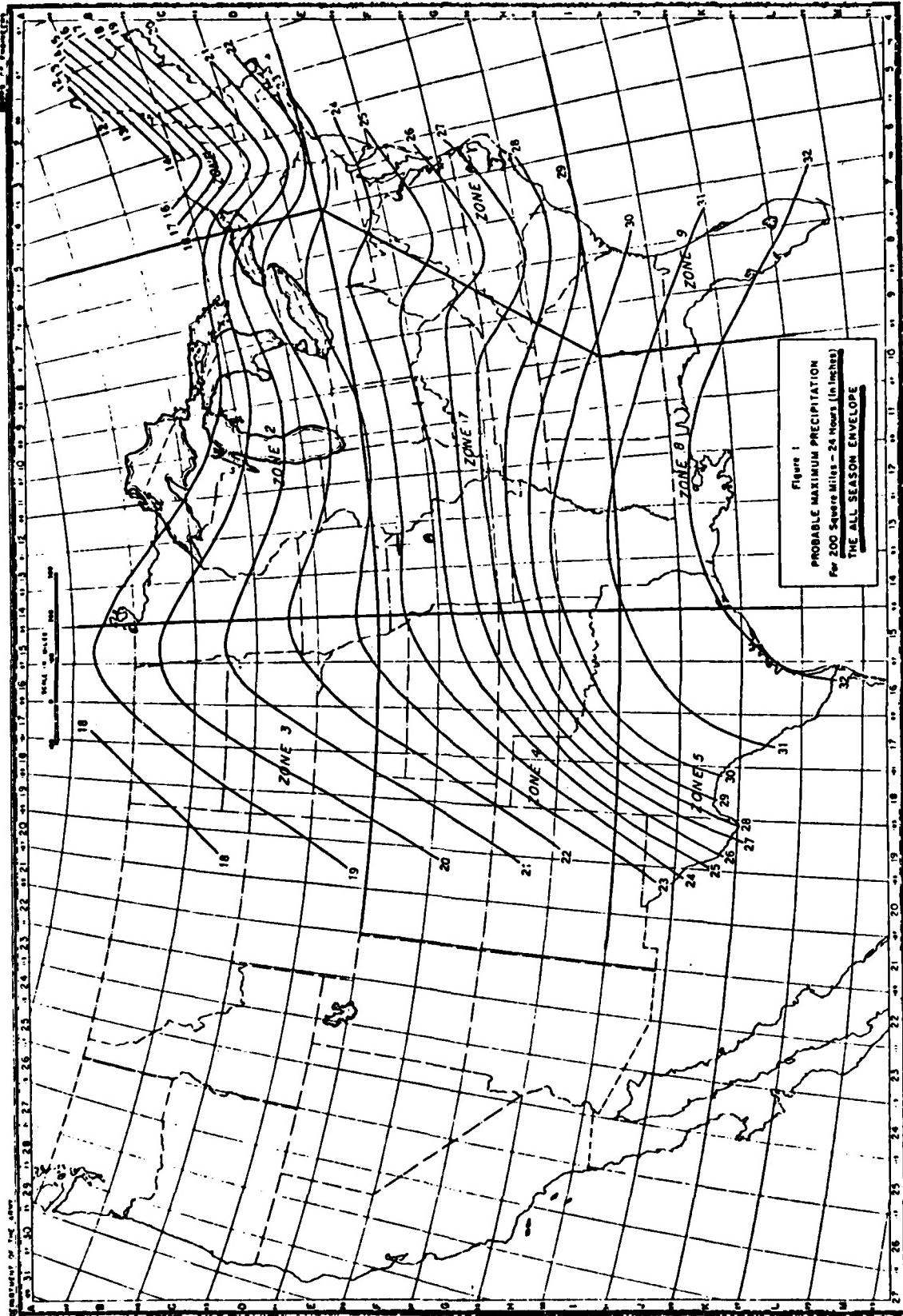
LONG.  $91^{\circ} 50' 38''$  LAT.  $39^{\circ} 10' 19''$ 

$$\Rightarrow PMP = 24.6'' \text{ (From Fig 1, HMR #33)}$$

3. DETERMINE BASIN RAINFALL IN TERMS OF PERCENTAGE OF PMP INDEX RAINFALL FOR VARIOUS DURATIONS :

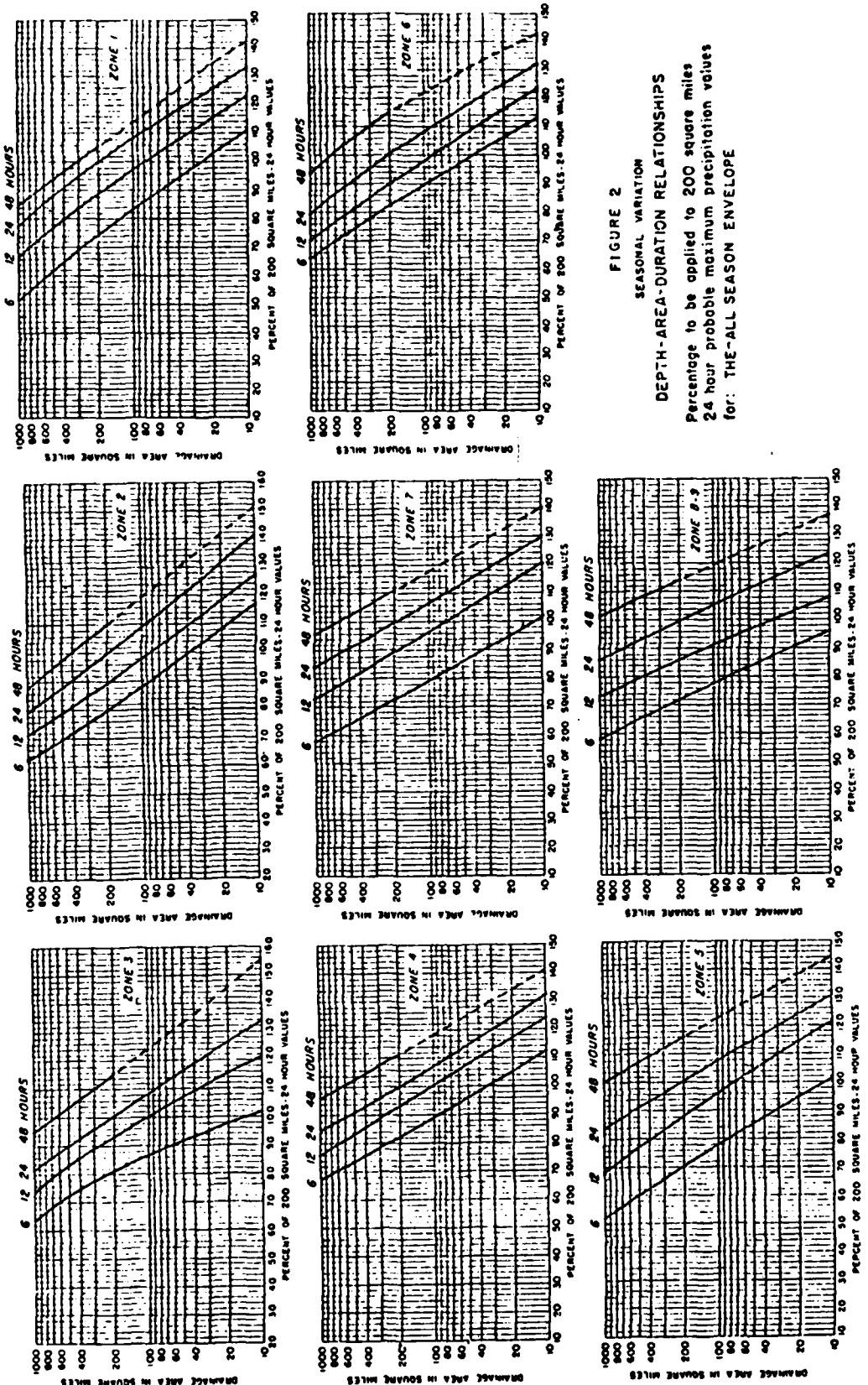
LOCATION LONG =  $91^{\circ} 50' 38''$  LAT =  $39^{\circ} 10' 19''$  $\Rightarrow$  ZONE 7

DURATION	PERCENT OF INDEX RAINFALL (%)	TOTAL RAINFALL (INCHES)	RAINFALL INCREMENTS (INCHES)	DURATION OF INCREMENTS (HRS.)
6	100	24.6	24.6	6
12	120	29.5	4.9	6
24	130	32.0	2.5	12



PMP FOR 200 SQ. MI 4  
24 HRS (WATERFALL)  
24.6"

DAM MO. C105  
LOCATION OF CENTROID  
1. WATCHED:  
LAT. 33° 10' 19" LONG. 41° 52' 34"



## ECI-4 ENGINEERING CONSULTANTS, INC.

DAM SAFETY INSPECTION - MISSOURI  
CFA LAKE DAM # MO 10105

SHEET NO. 1 OF

JOB NO. 1240

UNIT HYDRAULIC PARAMETERS

BY DNZ  
MAS

DATE 11/14

1. DRAINAGE AREA,  $A = 1870 \text{ ACRES} = 2.92 \text{ SQ. MI.}$
2. LENGTH OF STREAM = 2.15 MILES = 11,350 FT
3. ELEVATION AT DRAINAGE DIVIDE ALONG THE LONGEST STREAM  
 $H_1 = 825 \text{ FT}$
4. RESERVOIR ELEVATION AT SPILL WAY CREST,  $H_2 = 741 \text{ FT}$
5. DIFFERENCE IN ELEVATION,  $\Delta H = 84 \text{ FT}$
6. AVERAGE SLOPE OF STREAM =  $\frac{\Delta H}{L} = \frac{84}{11,352} = 0.74\%$
7. TIME OF CONCENTRATION
- BY KIRPICH FORMULA:  
 $T_c = \left( \frac{11.9 \times L^3}{\Delta H} \right)^{0.385} = \left( \frac{11.9 \times 11,350^3}{84} \right)^{0.385} = 1.14 \text{ HRS}$
  - BY VELOCITY ESTIMATE: AVG VEL = 2 CFS  
 $T_c = \frac{L}{V} = \frac{11,350}{2(60 \times 60)} = 1.58 \text{ HRS}$
- USE  $T_c = 1.14 \text{ HRS}$
8. LAG TIME,  $L_t = 0.6 \times 1.14 = 0.684 \text{ HR}$
9. UNIT DURATION;  $D \leq \frac{L_t}{3} = \frac{0.684}{3} = 0.228 > 0.167$   
USE  $D = 0.167$
10. TIME TO PEAK,  $T_p = \frac{D}{2} + L_t = \frac{0.167}{2} + 0.684 = 0.762$
11. PEAK DISCHARGE,  $q_p = \frac{484A}{T_p} = \frac{484(2.92)}{0.767}$   
 $q_p = 1842 \text{ CFS}$

EC-4 ENGINEERING CONSULTANTS, INC.

DAM SAFETY INSPECTION - MISSOURI

SHEET NO. 1 OF

C & A LAKE DAM (10105)

JOB NO. 1240-001

HYDROLOGIC SOIL GROUP AND CURVE NUMBER

BY HLB DATE 6-25-7

C & A LAKE DAM

HYDROLOGIC SOIL GROUP AND CURVE NUMBER

1. WATERSHED SOILS CONSIST PRIMARILY OF GROUP D SOILS. FOR HYDROLOGIC PURPOSES. ASSUME GROUP D FOR THE ENTIRE WATERSHED
2. MOST OF THE WATERSHED IS IN MEADOWS WITH SOME WOODED AND FARMLAND, AND MINIMAL RESIDENTIAL DEVELOPMENT. ASSUME THE HYDROLOGIC CONDITION OF THE WATERSHED IS GOOD

THUS. CN = 78 FOR AMC II

AND CN = 90 FOR AMC III

HEC1DB INPUT DATA



PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

RUNOFF HYDROGRAPH AT  
ROUTE HYDROGRAPH TO  
END OF NETWORK

10105

10105

INFLOW PMF AND ONE-HALF PMF HYDROGRAPHS

FLOOD HYDROGRAPH PACKAGE (HEC-1)  
DAM SAFETY VERSION JULY 1978  
LAST MODIFICATION 26 FEB 79

RUN DATE: 7/9/10/05,  
TIME: 10-13-06.

DAY SAFETY INSPECTION - MISSOURI

CIA LAKE DAM #1C105

PHF AND 50 PERCENT PHF DETERMINATION AND ROUTING

		JOB SPECIFICATION					
NR	NMR	NDAY	THR	TWIN	METRIC	IPLT	IPRT
300	0	10	0	0	0	0	0
		JCDER	NUIT	LNPNT	TRACE	0	0
		5	0	0	0	0	0

MULTI-PLAN ANALYSES TO BE PERFORMED  
NPLAN= 1 MRTIO= 2 LRTIO= 1

RTIOS= 1.00 .50

SUB-AREA RUFFOFF COMPUTATION

INPUT PMP INDEX RAINFALL AND RATIOS, INPUT SCS UNIT HYDROGRAPH PARAMETERS

IStage	ICOMP	IECON	ITADP	JPLT	JPRT	IName	ISAGE	IAUTO
10105	0	0	0	0	0	1	0	0
IMHYG	IUMG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNAME	LOCAL
1	2	2.92	3.00	2.92	1.00	3.00	0	0
SPFT	PMS	R6	PRECIP DATA					
0.00	24.60	100.00	120.00	130.00	R48	R72	R96	
LROPT	STARR	DLTKR	AT10L	ERAIN	STAKS	RT10K	STRTL	ALSPX
0	0.00	0.00	1.00	0.00	0.00	1.00	-1.00	RT10P
CURVE NO =	-90.00	WETNESS =	-1.00	EFFECT CN =	90.00			0.00
TC =	0.00	LAG =	*69					
STR10 =	0.00	RECEDION DATA						
QRC5N =	0.00							
UNIT HYDROGRAPH 23 END OF PERIOD ORDINATES. TC=	0.00	HOURS, LAG=	*69	VOL= 1.00				
212. 671. 1369. 1784. 1821. 1575. 1200.				556.	399.			
195. 157. 95. 68.				33.	24.	17.	13.	

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B-19

B-20

HYDROGENATION OF PROPENE

B-2

	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PEAK	325.	371.	105.	11.93	300.00	1827.	2222.				
CFS	236.										
INCHES											
MN											
AC-FT											
THOUS CU M											

#### HYDROGRAPH ROUTING

##### ROUTE HYDROGRAPH THROUGH CEA LAKE JSTNS 4 MILITARY SECTION

	1STSTG	ICOMP	ECOM	ITAPE	JPLT	JPAT	INATE	1STSTG	TAUTD
	101CS	1	Q	0	2	3	4	0	0
GLOSS	0.0	0.0	0.0	ROUTING DATA	101P	IPMP			
LOSS	0.0	0.0	0.0	101S	1	1			
VSIDS	0.0	0.0	0.0	LAG	A4544	X	TSK	101S-T	
				0	2.000	0.000	0.000	-741.	
STAGE	741.00	742.00	743.00	743.50	744.60	745.30	747.30	748.00	751.80
FLOW	0.00	149.0	419.00	515.00	1354.00	2659.00	4969.00	8268.00	23624.00
CAPACITY=	0.	164.	221.	725.	1196.	1421.	3663.		
ELEVATION=	733.	741.	743.	740.	755.	766.	770.		
CREL	SPWID	CODC	EXPM	ELEV	CODC	CAREA	EXPL		
	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

JAW DATA  
CAPC CMAX CMIN  
TANFL CODC EXPD 0.0 0.0

743.0 0.0 0.0

8268.00 1268.00

23624.00 1268.00

23624.00 1268.00

STATION 10102, PLAN 1, RATIO 1

END-OF-PERIOD HYDROGRAPH ORIGINATES

	OUTFLOW	0	0	0	0	0	0	0	0
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.	1.	1.	2.	3.	5.	7.	9.	11.	11.
2.	2.	2.	2.	11.	35.	39.	43.	47.	47.
3.	3.	3.	7.	7.	7.	7.	9.	9.	106.
4.	4.	4.	6.	6.	6.	7.	8.	8.	655.
5.	5.	5.	6.	6.	6.	7.	8.	8.	575.
6.	6.	6.	7.	7.	7.	8.	9.	9.	1174.
7.	7.	7.	8.	8.	8.	9.	10.	10.	1374.
8.	8.	8.	9.	9.	9.	10.	11.	11.	1393.
9.	9.	9.	10.	10.	10.	11.	12.	12.	2696.
10.	10.	10.	11.	11.	11.	12.	13.	13.	2393.
11.	11.	11.	12.	12.	12.	13.	14.	14.	2126.
12.	12.	12.	13.	13.	13.	14.	15.	15.	1596.
13.	13.	13.	14.	14.	14.	15.	16.	16.	1593.
14.	14.	14.	15.	15.	15.	16.	17.	17.	1593.
15.	15.	15.	16.	16.	16.	17.	18.	18.	1593.
16.	16.	16.	17.	17.	17.	18.	19.	19.	1593.
17.	17.	17.	18.	18.	18.	19.	20.	20.	1593.
18.	18.	18.	19.	19.	19.	20.	21.	21.	1593.
19.	19.	19.	20.	20.	20.	21.	22.	22.	1593.
20.	20.	20.	21.	21.	21.	22.	23.	23.	1593.
21.	21.	21.	22.	22.	22.	23.	24.	24.	1593.
22.	22.	22.	23.	23.	23.	24.	25.	25.	1593.
23.	23.	23.	24.	24.	24.	25.	26.	26.	1593.
24.	24.	24.	25.	25.	25.	26.	27.	27.	1593.
25.	25.	25.	26.	26.	26.	27.	28.	28.	1593.
26.	26.	26.	27.	27.	27.	28.	29.	29.	1593.
27.	27.	27.	28.	28.	28.	29.	30.	30.	1593.
28.	28.	28.	29.	29.	29.	30.	31.	31.	1593.
29.	29.	29.	30.	30.	30.	31.	32.	32.	1593.
30.	30.	30.	31.	31.	31.	32.	33.	33.	1593.
31.	31.	31.	32.	32.	32.	33.	34.	34.	1593.
32.	32.	32.	33.	33.	33.	34.	35.	35.	1593.
33.	33.	33.	34.	34.	34.	35.	36.	36.	1593.
34.	34.	34.	35.	35.	35.	36.	37.	37.	1593.
35.	35.	35.	36.	36.	36.	37.	38.	38.	1593.
36.	36.	36.	37.	37.	37.	38.	39.	39.	1593.
37.	37.	37.	38.	38.	38.	39.	40.	40.	1593.
38.	38.	38.	39.	39.	39.	40.	41.	41.	1593.
39.	39.	39.	40.	40.	40.	41.	42.	42.	1593.
40.	40.	40.	41.	41.	41.	42.	43.	43.	1593.
41.	41.	41.	42.	42.	42.	43.	44.	44.	1593.
42.	42.	42.	43.	43.	43.	44.	45.	45.	1593.
43.	43.	43.	44.	44.	44.	45.	46.	46.	1593.
44.	44.	44.	45.	45.	45.	46.	47.	47.	1593.
45.	45.	45.	46.	46.	46.	47.	48.	48.	1593.
46.	46.	46.	47.	47.	47.	48.	49.	49.	1593.
47.	47.	47.	48.	48.	48.	49.	50.	50.	1593.
48.	48.	48.	49.	49.	49.	50.	51.	51.	1593.
49.	49.	49.	50.	50.	50.	51.	52.	52.	1593.
50.	50.	50.	51.	51.	51.	52.	53.	53.	1593.
51.	51.	51.	52.	52.	52.	53.	54.	54.	1593.
52.	52.	52.	53.	53.	53.	54.	55.	55.	1593.
53.	53.	53.	54.	54.	54.	55.	56.	56.	1593.
54.	54.	54.	55.	55.	55.	56.	57.	57.	1593.
55.	55.	55.	56.	56.	56.	57.	58.	58.	1593.
56.	56.	56.	57.	57.	57.	58.	59.	59.	1593.
57.	57.	57.	58.	58.	58.	59.	60.	60.	1593.
58.	58.	58.	59.	59.	59.	60.	61.	61.	1593.
59.	59.	59.	60.	60.	60.	61.	62.	62.	1593.
60.	60.	60.	61.	61.	61.	62.	63.	63.	1593.
61.	61.	61.	62.	62.	62.	63.	64.	64.	1593.
62.	62.	62.	63.	63.	63.	64.	65.	65.	1593.
63.	63.	63.	64.	64.	64.	65.	66.	66.	1593.
64.	64.	64.	65.	65.	65.	66.	67.	67.	1593.
65.	65.	65.	66.	66.	66.	67.	68.	68.	1593.
66.	66.	66.	67.	67.	67.	68.	69.	69.	1593.
67.	67.	67.	68.	68.	68.	69.	70.	70.	1593.
68.	68.	68.	69.	69.	69.	70.	71.	71.	1593.
69.	69.	69.	70.	70.	70.	71.	72.	72.	1593.
70.	70.	70.	71.	71.	71.	72.	73.	73.	1593.
71.	71.	71.	72.	72.	72.	73.	74.	74.	1593.
72.	72.	72.	73.	73.	73.	74.	75.	75.	1593.
73.	73.	73.	74.	74.	74.	75.	76.	76.	1593.
74.	74.	74.	75.	75.	75.	76.	77.	77.	1593.
75.	75.	75.	76.	76.	76.	77.	78.	78.	1593.
76.	76.	76.	77.	77.	77.	78.	79.	79.	1593.
77.	77.	77.	78.	78.	78.	79.	80.	80.	1593.
78.	78.	78.	79.	79.	79.	80.	81.	81.	1593.
79.	79.	79.	80.	80.	80.	81.	82.	82.	1593.
80.	80.	80.	81.	81.	81.	82.	83.	83.	1593.
81.	81.	81.	82.	82.	82.	83.	84.	84.	1593.
82.	82.	82.	83.	83.	83.	84.	85.	85.	1593.
83.	83.	83.	84.	84.	84.	85.	86.	86.	1593.
84.	84.	84.	85.	85.	85.	86.	87.	87.	1593.
85.	85.	85.	86.	86.	86.	87.	88.	88.	1593.
86.	86.	86.	87.	87.	87.	88.	89.	89.	1593.
87.	87.	87.	88.	88.	88.	89.	90.	90.	1593.
88.	88.	88.	89.	89.	89.	90.	91.	91.	1593.
89.	89.	89.	90.	90.	90.	91.	92.	92.	1593.
90.	90.	90.	91.	91.	91.	92.	93.	93.	1593.
91.	91.	91.	92.	92.	92.	93.	94.	94.	1593.
92.	92.	92.	93.	93.	93.	94.	95.	95.	1593.
93.	93.	93.	94.	94.	94.	95.	96.	96.	1593.
94.	94.	94.	95.	95.	95.	96.	97.	97.	1593.
95.	95.	95.	96.	96.	96.	97.	98.	98.	1593.
96.	96.	96.	97.	97.	97.	98.	99.	99.	1593.
97.	97.	97.	98.	98.	98.	99.	100.	100.	1593.
98.	98.	98.	99.	99.	99.	100.	101.	101.	1593.
99.	99.	99.	100.	100.	100.	101.	102.	102.	1593.
100.	100.	100.	101.	101.	101.	102.	103.	103.	1593.
101.	101.	101.	102.	102.	102.	103.	104.	104.	1593.
102.	102.	102.	103.	103.	103.	104.	105.	105.	1593.
103.	103.	103.	104.	104.	104.	105.	106.	106.	1593.
104.	104.	104.	105.	105.	105.	106.	107.	107.	1593.
105.	105.	105.	106.	106.	106.	107.	108.	108.	1593.
106.	106.	106.	107.	107.	107.	108.	109.	109.	1593.
107.	107.	107.	108.	108.	108.	109.	110.	110.	1593.
108.	108.	108.	109.	109.	109.	110.	111.	111.	1593.
109.	109.	109.	110.	110.	110.	111.	112.	112.	1593.
110.	110.	110.	111.	111					

SUMMARY OF PMF AND ONE-HALF PMF FLOOD ROUTING

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS  
FLOWS IN CUBIC FEET PER SECOND (Cubic Meters per second)  
AREA IN SQUARE MILES (equivalent Kilometers<sup>2</sup>)

OPERATION	STATION	AREA	PLAN	RATIO 1	RATIO 2	RATIOS APPLIED TO FLOWS
HYDROGRAPH AT	10105	2.92 (7.56)	1	16650.	8325.	
ROUTED TO	10105	2.92 (7.56)	1	471.81(	215.41(	

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## SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1	ELEVATION STORAGE OUTFLOW	INITIAL VALUE 741.00 104. 0.	SPILLWAY CREST 741.00 104. 1.	TIME OF DAM 745.51 221. 515.		
RATIO OF FMF V.S. LEV	MAXIMUM RESERVOIR HEAD OVER CAM	MAXIMUM STORAGE AC-FY	MAXIMUM OUTFLOW CFS	DURATION CYCLE TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.80 .50	750.70 748.22	740 692	733. 591.	15.8** 6371.	16.51 11.67	16.50 16.57 0.00

B-25

PERCENT OF PMF FLOOD ROUTING  
EQUAL TO SPILLWAY CAPACITY

B-26

PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

RUNOFF HYDROGRAPH AT	10105
ROUTE HYDROGRAPH TO	10105
END OF NETWORK	10105

FLOOD HYDROGRAPH PACKAGE (HEC-1)  
DAM SAFETY VERSION JULY 1978  
LAST MODIFICATION 26 FEB 79

234 DATE 79/11/05 TIME 10.22.45.

**DAM SAFETY INSPECTION - MISSOURI  
C&A LAKE DAM (11035)  
PERCENT OF PMF DETERMINATION AND RUL**

MULTI-PLAN ANALYSES TO BE PERFORMED  
NPLAY = 1 NPTIO = 5 LPTIO = 1  
MLOSS = .025 .006 .007 .008 .009

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HYDROGRAPHIC PARAMETERS

	1STAQ	1COMP	IECON	ITAPE	JPLT	JPAT	INAME	ISAGE	IAUTO
10105	0	0	0	0	0	0	0	0	0
G	TABLE	SNAP	HYDROGRAPH	DATA					LOCAL
?	2.92	0.00	TASD	TRSPC	RATIO	1SN04	ISAME	0	
			2.92	1.30	0.050	0			
PMS	R6	PRECIP	DATA						R96
		R12	R12	324	399				

**UNIT HYDROGRAPH DATA**

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STRTG= 0.00 RECESSIVE DATA
GRCSY= 0.00 RITOR= 1.00
END-OF-PERIOD FLOW
CROSS-COVARIANCE COEFFICIENTS
PERIOD 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 79 80 81 82 83 84 85 86 87 88 89 89 90 91 92 93 94 95 96 97 98 99 99 100

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SUM 31.98 30.68 1.30 366746.  
( 812.0) ( 779.0) ( 33.0) ( 9818.75)

HYDROGRAPH ROUTING

ROUTE HYDROGRAPH THROUGH CMA LAKE DAM USING HIGHWAY SECTION

STAO	I COMP	IECON	ITAPL	IPPT	INAME	1 STAGE	IAUTO
I0105	1	0	0	0		0	0
GLOSS	CLOSS	Avg	ROUTING DATA	IPPT	IPMP	LSTP	
0.0	0.000	0.00	IPFS	IPMT		0	
HSTPS	HSTPL	LAG	AVGSS	TICK	STORM	ISPEAK	
1	0	0	0.000	0.000	-741.	-1	
STAGE	741.00	743.00	744.50	745.00	747.50	748.80	751.80
FLOW	0.00	149.00	515.00	1354.00	2507.00	4900.13	23624.00
CAPACITY=	0.	104.	221.	725.	1194.	1921.	3463.
ELEVATION=	733.	741.	743.	750.	755.	760.	770.
CREL	SEIDL	C238	EXPM	ELEV	COGL	C2PEA	FPL
741.0	741.0	0.0	0.0	0.0	0.0	0.0	0.0
TOPLL	JAM DATA	CODC	CODP	DAMWID			
		745.5	3.0	0.0			

PEAK OUTFLOW IS - 405. AT TIME 17.33 HOURS

PEAK OUTFLOW IS - 506. AT TIME 17.17 HOURS

PEAK OUTFLOW IS - 638. AT TIME 17.17 HOURS

PEAK OUTFLOW IS - 748. AT TIME 17.00 HOURS

PEAK OUTFLOW IS - 865. AT TIME 17.00 HOURS

B-29

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS  
 FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)  
 AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	APEA	PLAN	RATIOS APPLIED TO FLOWS				
				RATIO .05	RATIO .05	RATIO .05	RATIO .05	RATIO .05
HYDROGRAPH AT	10105	2.92	1	83%	99%	115%	135%	169%
	(7.56)	(	(	(23.57)(	(26.39)(	(53.30)(	(77.12)(	(42.03)(
ROUTED TO	10105	2.92	1	40%	50%	51%	74%	65%
	(7.56)	(	(	(11.47)(	(14.33)(	(17.63)(	(21.13)(	(24.51)(

B-30

## SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....	ELEVATION STORAGE OUTFLOW	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM	TIME OF				
					MAXIMUM DEPTH OVER DAM AC-FT	MAXIMUM STORAGE OUTFLOW CFS	DURATION 3HR TGP HOURS	M/X OUTFLOW HOURS	FAILURE HOURS
.05	742.95	0.00	203.	405.	0.00	0.00	17.33	0.00	0.00
.06	743.27	3.00	220.	506.	0.00	0.00	17.17	0.00	0.00
.07	743.48	*1.9	*34.	650.	2.01	17.17	1.00	0.00	0.00
.08	743.66	*36	248.	748.	2.67	17.00	1.00	0.00	0.00
.05	743.84	*54	267.	855.	3.17	17.00	1.00	0.00	0.00

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